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Special Edition on "Galamsey"

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Volume 5

Issue 2



Editors' Choice

The Ghana Academy of Arts and Sciences (2024)
Statement on illegal mining. HSI Journal 5(2):
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<https://doi.org/10.46829/hsijournal.2024.6.5.2.740-743>

About the cover page illustration

This aerial view shows the destructive consequence of illegal mining activities, locally known as "galamsey" on a forest ecosystem in Ghana. The once lush vegetation has been pillaged, leaving barren patches where trees and plants once thrived. Top soil has eroded, further devastating the land. Visible stagnant water are contaminated with mercury, a toxic by-product of galamsey that poses serious risks to human health.

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We look forward to hearing from you. Please feel free to contact us if you need any further clarification.

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The Logo is an *Adinkra* symbol rendered in the Akan language as *Nea onnim no sua a, ohu*. It is loosely translated into English as “the one who does not know but learns, gets to know.”



Editorial *Special Edition on Galamsey*

Welcome message from the Editor-in-chief

Professor Andrew Anthony Adjiei
Email: hsijournal@ug.edu.gh



I welcome readers to this Special Edition on galamsey. Galamsey, a local Ghanaian term is an amalgamation of “gather” and “sell” and encapsulates the informal illegal artisanal mining activities to extract gold, diamonds and precious minerals. Galamsey mining causes significant environmental destruction, rendering the soil infertile, polluting water bodies, and degrading the ecosystem. Galamsey is an urgent national crisis that demands immediate and collective action for resolution. Ghana is fighting against galamsey, and the Health Sciences Investigations (HSI) Journal supports this national effort.

The HSI Journal is pleased to present this Special Edition on Galamsey, featuring five selected original articles, a short communication from the Ghana Academy of Arts and Sciences, a medical case report that highlights the grim consequences of galamsey.

Galamsey, once a whisper now reverberates across our nation and has ravaging effects not only in the present but also for the future. Localized in certain regions in the past, it is beginning to rapidly spread its tentacles across the nation. In our capacity as stewards of the health sciences, we must lift the veil on this illicit affair, dissecting its impact on health and our ecosystems. This editorial calls for a multifaceted response to address galamsey's detrimental effects on the health and well-being of Ghanaians. Galamsey is not merely an economic or environmental issue; it is a public health crisis that necessitates immediate attention. The primary culprit in galamsey's health impact is mercury. When mercury and gold interact, they bind in a process called amalgamation.

This method is used to extract gold from ore. Mercury is toxic and has documented effects on the human body. Mercury can be absorbed by touch, inhalation, or consumption. Chronic exposure to mercury can affect the kidneys, lungs, digestive system, the nervous systems and other parts of the human body. It is a threat to the development of the child in utero and early life. As miners separate the gold from the mercury, the waste containing mercury seeps into the environment and contaminates our waterbodies and soil. This is how mercury becomes a part of our food chain. It is known to affect aquatic life and can be found in fish. Galamsey disrupts the delicate balance of ecosystems. The devastation of forests and the pollution of rivers not only jeopardize biodiversity but also disrupt the traditional livelihoods of communities. This can result in malnutrition and food insecurity, which can further compromise health. Additionally, the unsafe working conditions in galamsey mines expose miners to accidents often fatal and respiratory illnesses due to dust inhalation.

The complex fundamental causes of galamsey make it a long-term challenge to combat. Some individuals are motivated to pursue this perilous source of income through illegal mining due to poverty and unemployment. The issue is further exacerbated by corruption and weak enforcement of regulations within the mining sector. Additionally, the lucrative market for illegally mined resources is driven by the global demand for gold. The health science community has a crucial role to play in addressing galamsey. In the long term, fostering collaboration between health professionals, environmental scientists, marine and fisheries scientists, public health scientists, agricultural scientists, community stakeholders, journalists, security agencies and policymakers is vital. It is essential to aggressively intensify public awareness campaigns in order to inform communities about the health hazards associated with galamsey and to motivate them to report illegal mining activities.

Comprehensive research is essential to ascertain the extent of the long-term health effects of mercury exposure on exposed populations and to assess the impact of this harm on our waterbodies, soil, biodiversity, and food chain. This information has the potential to influence public health interventions and policy decisions. It is imperative to conduct health screenings in afflicted regions and to ensure that healthcare services are easily accessible. Furthermore, a step toward a healthier future is the exploration of alternative, sustainable mining practices that reduce environmental and health hazards. The lands must also be reclaimed through a concerted action by stakeholders through reforestation, soil rehabilitation, water purification activities. It is equally necessary to invest in education and offer alternative economic opportunities to those who are drawn to galamsey. Technology can also play a vital role in monitoring mining activity and identifying galamsey hotspots. It is imperative to address corruption and strengthen law enforcement.

....Editorial message from the Editor-in-chief

As the sun rises over the scarred lands in Ghana, it reveals a harrowing drab picture – a dance of environmental betrayal, greed, and desperation. A trail of mercury-laden rivers that potentially infiltrates our food chain, deforested landscapes, destroyed flora, displaced fauna, and fractured communities is left in the wake of “Galamsey”. let us recalibrate our moral compass. Our choices ripple beyond our borders, beyond our lifetimes and can have damaging consequences for our descendants. Galamsey is not just a menace; it is a mirror reflecting our values, our priorities. The canvas awaits our stroke. Will we paint a story of redemption or regret?

The battle to end galamsey is ongoing and victory is imperative. It is essential that every stakeholder recognizes the importance of this issue. A united front and consistent collaboration are crucial, as is leveraging all available resources to ensure the success of this endeavor.

The HSI Journal extends sincere gratitude to the Editorial Board members and reviewers for their invaluable contributions and suggestions in making this special publication possible. We also acknowledge the immense support and guidance provided by the Technical Team, Advisory Board, all authors, and publishers.

As Editor-in-Chief, I encourage authors and readers to share their feedback, suggestions, and concerns to help us maintain the HSI Journal's high standards of excellence.

Thank you

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The University of Ghana College of Health Sciences – the copyright owner, patron, and sponsor of the HSI Journal – has always shown a deep interest in the affairs of its constituent institutions. The Journal is indeed grateful to Professor Julius Fobil, the Provost of the College, for his immense support.

About the Editor-in-chief

Professor Andrew Anthony Adjei is a Professor of Immunology with over thirty years of biomedical and allied health sciences training and research experience. He is a Fellow of the following: Ghana Academy of Arts and Sciences (FGA), African Academy of Sciences (AAS), Ghana Association of Medical Laboratory Scientists (GAMLS) and African Sciences Institute (ASI). Professor Adjei has been Head of Department, University of Ghana (UG) School of Biomedical and Allied Health Sciences, Deputy Provost, College of Health Sciences (CHS), Director of Research, Innovation and Development (UG), Acting Director, Institutional Research and Planning Office (UG), Coordinator of Research, University of Ghana Medical School (UGMS), Editor-in-Chief, Ghana Journal of Allied Health Sciences, President of Ghana Association of Medical Laboratory Scientists, Project Coordinator, Transdisciplinary Training for Resource Efficiency and Climate Change Adaptation in Africa, Project Coordinator, Building Stronger Universities (Partnership between UG and Universities in Denmark), Project Coordinator, Fogarty Global Health Fellows Training Programme (Partnership between UGMS and University of Morehouse School of Medicine, Atlanta, Georgia, USA), and Project Coordinator, Minority in Health Research Training (Partnership between UGMS and University of Morehouse School of Medicine). Professor Adjei was the immediate past Coordinator of the Worldwide Universities Network and the Australia-Africa Universities Network. Currently, he is the Chairman of the following: Ethics and Protocol Review Committee, CHS Public Lecture Series and Scientific Conference Planning Committee, CHS Newsletter (In Focus), CHS Library Refurbishment Committee, Member of Korle Bu Teaching Hospital Institutional Review Board and the Coordinator, MPhil Programme in Immunology, at the Department of Pathology, UGMS. Professor Adjei is a reviewer of several clinical and biomedical Journals globally. He has served on various UGMS and UG committees and currently serves on both the UG and CHS Academic Boards.

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Commentary

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“Help ‘our’ unbelief” on gamamsey in Ghana

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Special Edition on Gamamsey

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In this issue of the Journal, readers will find several articles on one of the most difficult problems bedevilling our nation in recent times, i.e., artisanal surface mining - popularly known as *gamamsey*. A lot has already been written on the destructive effects of this phenomenon and practice on our natural ecosystems and biodiversity. Many organisations and individuals, including professional and religious bodies, civil society organisations, clergy and traditional leaders have at various times, condemned the practice and lent their voices and support in the bid to find a solution to the menace. However, the fact that *gamamsey* persists and may even be thriving despite the wider societal disapproval and not least, the immense effort and resources invested towards curbing the practice is a mirror of how pervasive and deeply entrenched it may be. Indeed, some of our compatriots have, rightly so, labelled *gamamsey*, an “existential threat” to our nation.

In a paper titled, “*Decentralisation, informal mining, and environmental health: a political ecology perspective on Ghana’s mineral wealth management*” in the Journal [1], Adam, examines the ramifications of decentralising natural resource governance and empowering local communities. The author advances a case for the reasons why this approach may facilitate agency of local communities and suggests how such empowerment may be a sustainable approach. An attractive concept and not least because of its alignment with the ethos of traditional land ownership systems – which are thought to be custodial in trust for the people. However, an apparent inadequacy of this concept would be its inadequacy to explain or rationalise the blatant *gamamsey*-associated exploitation and devastation of land,

farms, water bodies and dwellings in some communities even where this concept of custodial land is supposed to be applicable. The exposition and explanations of the relevant political, legal and social concepts proffered by Kuditchar [2] in a paper titled “*decoding the persistence of gamamsey in Ghana: the meta-contradictions of neutered law*” perfectly expounds on the contextual factors that may be responsible for perpetuating the paradox. Alas, *gamamsey* it is said is driven by (powerful) mighty actors, and we may simply be witnessing heralding manifestations of the tensions between norms of a bygone era and the aspirations of a *brave new world*.

Awemomom and colleagues [3] enumerate known risks associated with exposure to heavy metals and other chemicals used in artisanal mining, in a review paper titled “*Health risks and birth defects associated with exposure to gamamsey-related pollutants*.” The authors recommend that bioavailability and toxicological studies as complementary to the wide variety of the other ongoing studies, a suggestion that is fully endorsed.

Asare and colleagues [4] in another review article titled, “*vulnerability to infectious diseases and risk reduction measures among gamamsey gold mining communities in Ghana*,” throw light on the biological and other linkages between *gamamsey* activities and prevalent infectious diseases while elucidating aspects of the *reservoir-environment-disease* nexus. Their recommendations do not deviate much from public health orthodoxies. However, they have succinctly made recommendations on strides we should be making as a community. The paper also reminds us poignantly, of the critical need to safeguard gains made in the control of communicable diseases, especially as we have begun to grapple with an escalating burden of non-

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communicable diseases. The case report by Issaka and colleagues [5], of a silicosis-pneumothorax-respiratory failure cascade, exemplifies a certain direction should the present trajectory we seem to be traversing regarding galamsey, remains unaltered.

Opoku et al., present primary data in their paper titled, “*Environmental exposure and potential health impact of heavy metals in previous mining communities in Ghana*” to confirm anticipated high levels of mining-associated pollutants in water, soil, food, and vegetation from abandoned land in galamsey communities [6]. Given the data shown, it is simply difficult to over-emphasize and yet impossible to overlook how lenient and charitable the authors’ call for “remediation and reclamation of affected land” and ‘enforcement of mining restrictions and regulations’ appear.

Finally, in a paper titled, “Statement on illegal mining” [7], the Ghana Academy of Arts and Sciences (GAAS) in a no holds barred style, pivots to the crux of the matter and in the starkest terms imaginatively: “*Ghana is on the brink of an ecological, health and social disaster as a result of illegal mining...and ‘we are rapidly approaching the precipice....’*” The Academy declares it “*can no longer sit in silence*” and, in characteristic fashion, trace the evolution of the historical and legal framework, outline the relevant biological, environmental, economic, health and socio-

cultural concerns. Importantly, a way forward has been proposed, a direct appeal has been made to the powers that be to declare a moratorium on illegal mining and revoke legislation that has provided the grey loopholes that have been exploited by its practitioners to perpetuate the menace.

The seven papers published in this issue of HSI Journal on galamsey, an aggregation of ideas, expertise and thoughts, presents an opportunity to raise yet, another ‘silent voice’ in the quest to finding a solution to the menace. Within the context of our craft, there is an imposed imperative on us to ensure we have prepared the right calibre of fit-for-purpose (human) capacity capable of addressing the problem as it evolves. Within the context of our mandate in the healthcare delivery space, our obligation lies in ensuring the means and preparedness to anticipate, quantify, and characterise the magnitude and trajectory of health consequences from a preventive, diagnostic, curative and holistic perspective. Daunting a task this may appear, given our circumstances, C. S. Lewis, quotation that “*Hardships often prepare ordinary people for an extraordinary destiny*” may be appropriate. The sentiments conveyed in the GAAS Statement on the galamsey conundrum is instructive as it is liberating, and in a way that makes it easy to conjure in the present, imagery of the circumstances within which the desperate cry, “*Help thou mine (our) unbelief,*” was uttered in Mark 9:23 (New King James Bible).

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Original Research Article

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Environmental exposure and potential health impact of heavy metals in previous mining communities in Ghana

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Special Edition on Galamsey

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Abstract

Heavy metal exposure arising from metal mining is a significant source of pollution in sub-Saharan Africa. In Ghana, concerns have been heightened due to increasing artisanal mining activities. Although efforts are being made to curb illegal mining activities, including a ban on artisanal mining by the government of Ghana, the devastating impacts of mining activities can persist in the environment for a long period. This study was carried out to assess the impact of mining activities on the exposure of toxic and potentially toxic metals in food, vegetation, soil and water samples from communities where mining activities have been halted for several years. The samples were digested using a microwave digestion system employing a mixture of nitric acid and hydrogen peroxide and analysed for mercury (Hg), lead (Pb), chromium (Cr), copper (Co), manganese (Mn), zinc (Zn), arsenic (As), cadmium (Cd), cobalt (Co), nickel (Ni) and iron (Fe), using an inductively coupled plasma - mass spectrometer (ICP-MS). The results showed generally elevated levels of metals in water, food, vegetation and soils. For example, in vegetation, the average concentrations of Pb, Hg, Cd, and As were 198 µg/kg, 303 µg/kg, 75 µg/kg, and 519 µg/kg, respectively, while the average levels of As and Pb were 11,111 µg/kg, and 3,518 µg/kg, respectively, in soil samples collected from abandoned mining sites. Food crops (cassava and plantain samples) grown in abandoned mining fields had elevated levels of Pb (602 µg/kg) and Hg (15.7 µg/kg). Based on our findings of widespread exposure, high concentrations, and potential health risks posed by these metals, proactive measures for the reclamation and remediation of affected land are needed to protect the environment and human lives in these previous mining communities.

Keywords: Mining, galamsey, food system, water, health risk, heavy metals, Ghana

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INTRODUCTION

The concern for environmental sustainability is growing rapidly on a global scale. This is the result of increasing anthropogenic activities such as unsustainable agriculture, construction, deforestation, industrialisation, mining and pesticide application. The mining industry represents one of the largest and most economically viable ventures in the world. The industry has gradually expanded its scope from conventional small-scale methods to large-scale mining [1]. In Ghana, most small-scale artisanal miners, known as ‘galamseyers’, are indigenous

unemployed youngsters with no prior mining training or experience who engage in surface mining, often without a licence [2]. Ghana, formally known as the Gold Coast, is one of the world’s top gold producers [3], and artisanal small-scale mining (ASM) is a significant source of gold production [4]. The mining industry contributes significantly to the country’s gross foreign exchange earnings [5]. At the same time, the sector has become a major contributor to environmental degradation and a major source of pollution due to the proliferation of indiscriminate mining activities [6]. Pollution from artisanal small-scale mining activities creates a significant pollution burden on local communities due to proximity to mining and may be associated with increased adverse impacts on food, water and vegetation in communities.

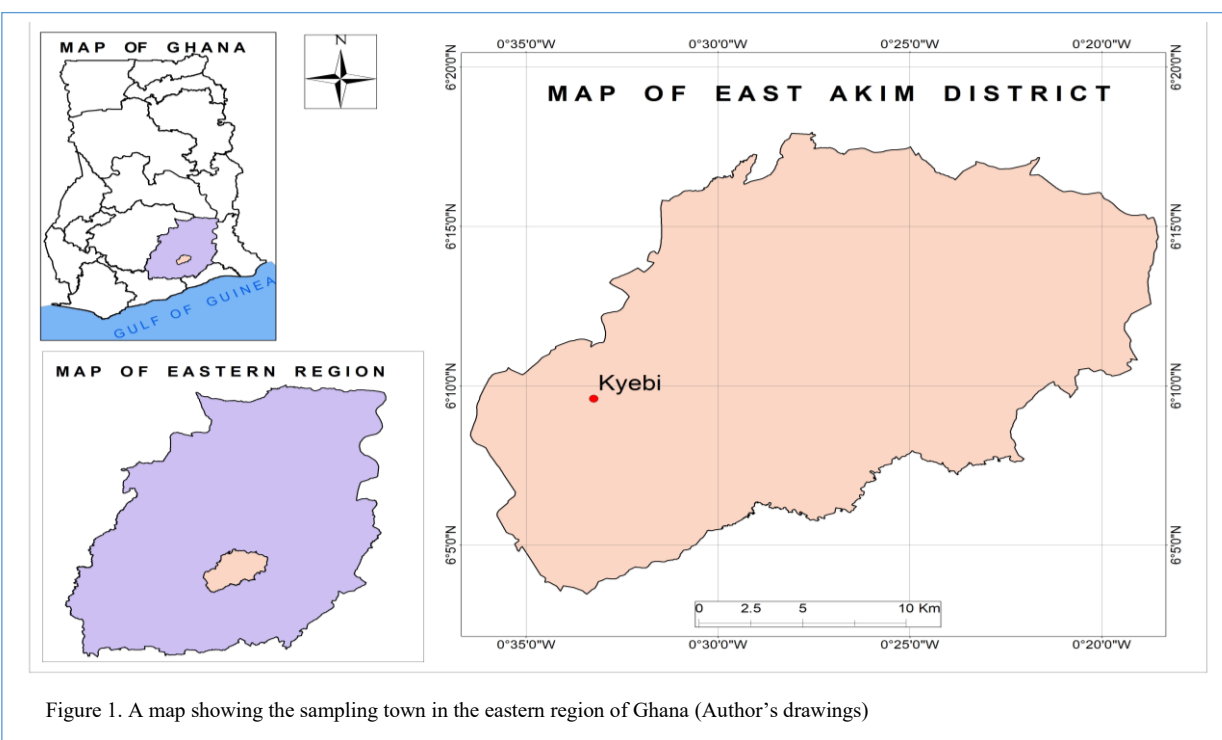
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Among the several harmful impacts associated with the mining industry, exposure to potentially toxic elements has been of great concern. This is a result of the release of metals and metalloids from the earth's crust during mining operations, as well as the use of metals such as mercury during processing. The release of these potentially harmful metals from mining areas has been associated with adverse human and environmental health outcomes. While metals such as copper, zinc and manganese are necessary for various metabolic processes, they can be toxic in large doses. On the other hand, elements such as cadmium, arsenic, lead, and mercury have no known role in the body and are toxic even at low concentrations [7]. In general, toxic metals pose a growing threat to ecosystems and human health due to their ability to persist, bioaccumulate, and biomagnify over time, with potentially devastating impacts [8,9]. For example, studies show that years after their active service, small-scale mines can continue to be a significant contributor to heavy metal contamination in the environment [10].

Furthermore, due to the limited land for agricultural purposes, mining communities tend to use abandoned mined land for agricultural activities, often without the necessary reclamation measures. Within such abandoned mining communities, heavy metal exposure may occur through various routes such as dust inhalation, direct ingestion, dermal contact, and the consumption of crops cultivated on these abandoned mining lands [11]. The results of several studies in Ghana and elsewhere point to the significant contribution of mining activities to heavy metal exposure. Akoto et al. (2023) reported that heavy

metals Hg, Pb, As, Cd, Cr and Fe were present in higher concentrations in the top soils of a mining town in the Northern region of Ghana compared to a control site [12]. Similar findings have been reported at various locations in southern Ghana [13,14]. Mining activities have also been shown to have significant impacts on water bodies, including rivers and sediments [14,15,16], as well as vegetation and crops [17,18]. In general, mining activities are found to play an important role in the exposure and transport of metal contaminants in the environment [19,20]. In recent years, concerns about the scale of destruction associated with ASM operations in Ghana, such as deterioration of water quality, destruction of forests and farms, and severe land degradation, have led to public outcry and a subsequent ban on artisanal-scale mining activities. Although the enforcement of the ban remains a challenge, the potential adverse impacts of exposure to potentially toxic metals through the consumption of water, food and environmental interaction within mining communities remain high. Evidence from the literature points to elevated levels of heavy metals in active mining communities [21,22]. However, there is limited knowledge about the levels, exposure, and impact of heavy metals from previous mining communities.

This study provides knowledge on the levels of heavy metals in food, water, vegetation, and soil samples from previous mining communities and estimates the health impacts of exposure in these communities. The results obtained were compared to those of the Food and Agriculture Organization and World Health Organization (FAO/WHO) standards.



MATERIALS AND METHODS

Geographical description of the sampling area

The sampling area is located in Kyebi, the administrative capital of the East Akim Municipality in the Eastern Region of Ghana (Figure 1). The municipality is situated within the moist semi-deciduous forest region of the country. The area encompasses forest reserves covering approximately 108.8 square kilometres, including a part of the Atiwa forest reserve [23]. The area is reported to contain granite rocks that contain several mineral deposits, including gold, diamond, and bauxite [24]. Soils in the area are known to be suitable for the cultivation of cash crops, including cocoa, coffee, palm oil, and cola, as well as food crops such as cassava, plantain, yam, and maize.

Sampling and preparation of samples

Samples of soil, cassava, plantain, turkey berry fruits (*Solanum torvum*), and *Chromolaena odorata* (locally called acheampong) leaves were collected from various abandoned mine sites in up to five different communities of the town. In all communities visited, mining sites were reported to have ended for at least ten years. Labelling was done according to the sites visited for easy identification. Soil samples were obtained from at least five different sites where mining had previously been carried out. All soil samples were obtained from shallow pits at different mining sites. At each location, six to ten samples were obtained, and a composite sample was formed from the individual samples. The samples were collected in clean polyethylene bags, sealed, and sent to the laboratory for sample preparation and analysis. Cassava and plantain samples were obtained from three communities. The samples were peeled and cut into smaller pieces to ensure faster air drying. Vegetation samples were obtained from the five communities visited. In all communities, three to five plant samples were obtained, and a composite sample was prepared for each community. The soils, *Solanum torvum* fruits, and *Chromolaena odorata* leaves were air-dried for two weeks. The soil samples were sieved using a 150-micrometre sieve. All other samples were pulverised using a stainless steel blender prior to digestion. Where available, control samples were obtained several kilometres (≥ 10 km) from abandoned mining sites for comparison.

Microwave digestion

Approximately 1.0 g of each sample was accurately weighed using an analytical balance (KERN PLJ). The samples were then placed in microwave digester vessels (Milestone ETHOS UP) and digested with 5 mL of HNO_3 and 3 mL of H_2O_2 . The microwave digester was operated using the following parameters: a temperature of 170 °C, a power of 1000 watts and a pressure of 50 bar for a total duration of 50 minutes (split into two runs of 25 minutes each). The samples were digested for one hour and allowed to cool. The digest was quantitatively transferred into graduated centrifuge tubes and diluted to the 25 mL mark with deionised water after washing the walls of the vessel.

The 25 mL solution was transferred and stored in sample bottles for analysis.

ICP-MS analysis

Heavy metal concentrations of Hg, Pb, Cr, Co, Mn, Zn, As, Cd, Co, Ni, and Fe were determined using an inductively coupled plasma mass spectrometer, ICP-MS (Agilent 7700 series) equipped with MassHunter Workstation software. The ICP-MS device was calibrated with standards for all relevant metals of interest prior to the analysis of the samples. The results of the metal analysis were corrected using reagent blanks.

Reagents

All reagents and chemicals used were of analytical grade. Concentrated HNO_3 (65%) and H_2O_2 (30%) were obtained from Merck (Darmstadt, Germany). A multielement standard solution comprising all relevant metals was procured from VWR Chemicals (Belgium). Standard solutions were prepared from the 100 mg / L stock standard in 2% HNO_3 . Calibration standard solutions were prepared from the stock multielement standard by serial dilution.

Quality assurance

Sample bottles and glassware used were cleaned with metal-free detergent and thoroughly rinsed with deionised water. The glassware was soaked in 10% HNO_3 for about 24 hours to remove metal particles that adhere to the glass surface. Distilled water was used in the preparation of all the solutions and stored in a capped plastic bottle. Blank solutions were prepared using distilled water, chemicals, and reagents to digest the samples. ICP-MS readings of the samples were corrected by using the results of the analysis of the blanks.

RESULTS AND DISCUSSION

The concentrations of 11 metals in the various sample types are reported in Tables 1-4. The findings show a wide range of concentrations among the various metals and samples from within the various communities and mining sites. The water samples from within the communities consisted of three main types: river water, groundwater/borehole water, and packaged water (sachet / bottled). The pH of the water samples ranged from 5.71 – 7.48, with a mean value of 6.57 (SD 0.65), reflecting the slightly acidic conditions of the water within the communities. Similar findings have been reported [25,26]. Wells constitute the predominant source of water in the communities studied. On the contrary, the river water appeared to be of lower quality on visual inspection, largely due to apparent high turbidity. In this study, river water samples recorded the highest pH value of 7.48.

Heavy metals in water

The levels of metals in water were generally lower than the levels in food, vegetation, and soils. This is expected given the generally protected nature of the water samples evident in boreholes. As expected, Mn and Fe showed the highest concentrations in the water samples, reflecting their general

abundance in nature. Fe concentration ranged from 2.07 - 721 µg/L with an average value of 207 (SD 10 µg/L). More importantly, the highest value of Fe was observed in river water, possibly influenced by mining activities within communities. This value, as well as two (2) of the borehole samples, exceeded the accepted value of Fe in drinking water based on WHO and the United States Environmental Protection Agency (USEPA) standards. However, the concentrations in this study are generally lower than those reported in the water of active mining sites [25,27]. The lower values reported may reflect the protection provided by underground/boreholes, as well as differences in active mining activities at the time of sampling. The Mn concentration ranged from 158.2 - 339 µg/L with an average of 237 (SD 10 µg/L). These values are all above the WHO (100 µg/L) and USEPA (50 µg/L) recommended limits for drinking water. These findings agree with reports of similar studies conducted in the Tarkwa metropolis in borehole water [28]. However, Bempah and Ewusi et al. (2016) reported lower levels of Mn in drinking water (98.45 - 143.26) than those recorded in this study [29]. Although Mn is a natural constituent of groundwater, elevated levels of Mn can be attributed to its increased exposure to the environment through activities such as mineral mining in the communities studied.

Furthermore, Fe and Mn have been reported to have key associations with gold-bearing rocks mined in Ghana, possibly explaining their abundance in study communities. The levels of Cr, Co, Cu, Ni, and Pb ranged from 0.010 - 6.6 µg/L, 1.95 - 7.8 µg/L, 1.03 - 13.3 µg/L, 0.60 - 9.5 µg/L and 2.0 - 6.6 µg/L respectively. The concentrations of Cr, Co, Cu, Ni, and Pb were below the allowable limit of WHO and USEPA for drinking water, likely reflecting their low natural levels in the environment. Similarly, Cd and Hg levels were below detection limits in almost all samples. In general, the concentrations of metals in the water samples varied in the order Mn>Fe>Cu>Pb>Cr>Ni>Co>Cd>Hg

and were largely influenced by the source of water and its exposure to mining activities, underbearing rocks, and pH of the waterbody [30,31]. pH is vital in the nature and mobility of metal elements in water. Given this, the slightly acidic nature of the water samples may have contributed to the levels reported in this study.

Heavy metals in vegetation

The choice of *Solanum torvum* and *Chromolaena odorata* was due to their abundance in almost all the sites studied. These two plants were found to grow wild in almost all abandoned mining sites visited. Metal concentrations (µg/kg) of metals in *Solanum torvum* ranged from 6,515 - 9,732 for Zn, 6.42 - 22.41 for Pb, 2.07 - 6.19 for Hg, 10,610 - 15,529 for Cu, 234.6 - 937.8 for Cr, 2.11 - 4.18 for Cd and 19.42 - 62.1 for As. Similarly, mean *Chromolaena odorata* concentrations ranged from 8,045 to 14,620 for Zn, 125.44 to 254.2 for Pb, 114.6 to 491.7 for Hg, 13,837 to 20,732 for Cu, 968.3 to 2196 for Cr, 52.9 to 86.3 for Cd and 230.4 - 711.9 for As. In both sets of samples, the levels of Zn, Cu, Hg, and Cr exceeded the WHO-recommended limits. More importantly, the control samples from the communities had significantly high levels of these metals, reflecting the generally elevated levels of potentially toxic metals in the communities studied. It is likely that elevated levels may reflect the higher ability of these plants to accumulate these metals. The high levels in *Solanum torvum* are of great concern given their use as an important vegetable, particularly among nursing mothers, mainly as a source of iron. The findings of these two plants provide an indication that the vegetation within these communities may contain elevated levels of metals, possibly at potentially toxic levels. This portends considerable environmental risks, given their possible exposure to plants, crops, animals, and humans [32]. The results obtained in this study are generally lower than those reported in similar studies in other locations [33,34]. These results reflect the general persistence of metal exposure

Table 1. pH and mean concentration (µg/L) of heavy metals in different sources of water in communities

Sample	pH	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb
Packaged water-1	6.20 ±0.02	-	0.01 ±0.02	3.09 ±0.06	2.6 ±0.1	2.1 ±0.5	-	-	0.6 ±0.2	6.6 ±0.2
Packaged water-2	5.71 ±0.08	-	0.052 ±0.007	1.95 ±0.07	7.1 ±0.2	2.1±0.1	-	-	0.7 ±0.2	2.0 ±0.1
River water	7.48 ±0.22	-	1.5 ±0.2	3.6 ±0.2	3.8 ±0.2	721 ±7	-	163 ±2	2.0 ±0.2	5.1 ±0.1
Borehole -1	6.72 ±0.12	-	6.6 ±0.2	4.8 ±0.2	4.63 ±0.07	14.6 ±0.4	-	223 ±10	9.5 ±0.4	3.48 ±0.07
Borehole -2	6.22 ±0.04	0.3 ±0.1	1.78 ±0.06	7.8 ±0.3	12.6 ±0.3	321 ±6	-	301 ±5	4.6 ±0.4	5.2 ±0.1
Borehole -3	6.31 ±0.05	-	0.9 ±0.1	2.8 ±0.3	13.3 ±0.3	145 ±2	-	158±10	3.3 ±0.1	2.07 ±0.07
Borehole -4	7.37 ±0.04	-	0.09 ±0.03	3.16 ±0.05	1.03 ±0.09	246 ±4	-	339 ±8	1.1±0.1	3.51 ±0.05
Mean	6.57 ±0.65	0.04 ±0.01	1.6±0.3	3.9±0.4	6.4±0.5	207±10	-	237 ±10	3.1±0.7	4.0 ±0.3
WHO Limit	6.5-9.5	3	-	50	2500	300	6	100	-	10
US EPA Limit	6.5-8.5	5	-	100	1300	300	2	50	70	15

Cd=cadmium, Co=cobalt, Cr=chromium, Cu=copper, Fe=iron, Hg=mercury, Mn=manganese, Ni=nickel, Pb=lead

WHO= World health Organization

US EPA= United State Environmental Protection Agency

through mining activities and their possible impact on ecosystems over time [10].

Levels of heavy metals in cassava and plantain samples

The mean concentrations ($\mu\text{g/kg}$) for Zn, Pb, Hg, Cu, Cr, Cd, and As in plantain fruit samples were $2,309.9 \pm 0.8$, 7.85 ± 0.04 , 4.81 ± 0.09 , 2721.1 ± 0.9 , 7.9 ± 0.2 , 0.74 ± 0.02 and 2.74 ± 0.02 , respectively. The results of these metals in

the plantain peels were significantly higher than in the fruits. Nonetheless, the findings from both sets of plantain samples revealed values within the acceptable limits. Similar studies carried out in food samples generally presented higher values for Zn, Pb, Cu, Cr, and Cd than those obtained in this study [34]. The mean concentrations ($\mu\text{g/kg}$) of metals in cassava samples were 7179 for Zn, 602 for Pb, 3.2 for Hg, 784 for Cu, 36 for Cr, 8.1 for Cd, and

Table 2. Mean concentration ($\mu\text{g/Kg}$) of heavy metals in vegetation

Sample	Zn	Pb	Hg	Cu	Cr	Cd	As
Turkey berry (Control)	5811 $\pm$ 30	8.7 $\pm$ 0.8	1.4 $\pm$ 0.2	9203 $\pm$ 30	108 $\pm$ 10	2.09 $\pm$ 0.03	11.8 $\pm$ 1.2
Turkey berry -1	9732 $\pm$ 20	22.4 $\pm$ 0.4	2.2 $\pm$ 0.8	15529 $\pm$ 40	235 $\pm$ 20	3.25 $\pm$ 0.02	19.4 $\pm$ 1.5
Turkey berry -2	6515 $\pm$ 32	19.5 $\pm$ 0.7	6.2 $\pm$ 0.8	10610 $\pm$ 32	938 $\pm$ 100	4.18 $\pm$ 0.08	62.1 $\pm$ 3.0
Turkey berry -3	7985 $\pm$ 34	6.4 $\pm$ 0.5	2.1 $\pm$ 0.9	11972 $\pm$ 41	330 $\pm$ 30	2.11 $\pm$ 0.06	26.3 $\pm$ 2.2
Average value	8077 $\pm$ 1600	16.1 $\pm$ 8.5	3.5 $\pm$ 2.3	12704 $\pm$ 2500	501 $\pm$ 380	3.2 $\pm$ 1.0	36 $\pm$ 22
<i>Chromolaena odorata</i> (Control)	19784 $\pm$ 70	133 $\pm$ 10	8.2 $\pm$ 2.6	12293 $\pm$ 70	1095 $\pm$ 30	18.6 $\pm$ 6.0	104.6 $\pm$ 2.2
<i>Chromolaena odorata</i> -1	14620 $\pm$ 30	254 $\pm$ 90	492 $\pm$ 80	16006 $\pm$ 30	2196 $\pm$ 60	84.2 $\pm$ 20	711.9 $\pm$ 9.4
<i>Chromolaena odorata</i> -2	13535 $\pm$ 30	125 $\pm$ 80	115 $\pm$ 40	20732 $\pm$ 60	968 $\pm$ 10	86.3 $\pm$ 20	230.4 $\pm$ 30.3
<i>Chromolaena odorata</i> -3	8045 $\pm$ 20	215 $\pm$ 90	303 $\pm$ 20	13837 $\pm$ 60	1520 $\pm$ 50	52.9 $\pm$ 10	614.6 $\pm$ 14.0
Average value	12067 $\pm$ 3500	198 $\pm$ 70	303 $\pm$ 190	16858 $\pm$ 3500	1561.5 $\pm$ 620	75 $\pm$ 20	519 $\pm$ 250
WHO Limit	5000	300	10	10000	300	200	-

Cd - cadmium, Cr - chromium, Cu - copper, Hg - mercury, Mn - manganese, Pb - lead, Zn - zinc

WHO - World health Organization

Table 3. The mean concentration ($\mu\text{g/Kg}$) of heavy metals in cassava and plantain samples

Sample name	Zn	Pb	Hg	Cu	Cr	Cd	As
Plantains	2,310 $\pm$ 80	7.9 $\pm$ 1.4	4.81 $\pm$ 2.0	2721 $\pm$ 90	7.9 $\pm$ 2.0	0.74 $\pm$ 0.20	2.74 $\pm$ 0.22
Plantain Peels	8196 $\pm$ 100	67.8 $\pm$ 8.0	4.2 $\pm$ 1.0	12845 $\pm$ 200	151 $\pm$ 20	2.69 $\pm$ 0.60	37.9 $\pm$ 7.0
Cassava	7179 $\pm$ 190	602 $\pm$ 180	3.2 $\pm$ 1.0	784 $\pm$ 160	36 $\pm$ 8	8.1 $\pm$ 1.0	BDL
Cassava Peels	10,529 $\pm$ 200	295 $\pm$ 60	15.7 $\pm$ 10	2586 $\pm$ 30	1657 $\pm$ 40	12.9 $\pm$ 0.8	221 $\pm$ 40
Cassava (Control)	3220 $\pm$ 90	42 $\pm$ 10	0.4 $\pm$ 0.1	1223 $\pm$ 100	BDL	6.5 $\pm$ 1.0	BDL
FAO/WHO Limits	50000	300	-	30000	20000	2000	-

Cd-cadmium, Cr-chromium, Cu-copper, Hg-mercury, Mn-manganese, Pb-lead, Zn-zinc

WHO - World health Organization

FAO - Food and Agriculture Organization

Table 4. The mean concentration ($\mu\text{g/Kg}$) of heavy metals in soils from five communities

Sample Name	Zn	Pb	Hg	Cu	Cr	Cd	As
Soil Sample-1	6885 $\pm$ 100	3232 $\pm$ 200	8.04 $\pm$ 0.07	10640 $\pm$ 400	16301 $\pm$ 400	7.54 $\pm$ 0.40	13049 $\pm$ 100
Soil Sample-2	9634 $\pm$ 200	5670 $\pm$ 200	20.7 $\pm$ 0.6	19298 $\pm$ 500	28078 $\pm$ 700	15.54 $\pm$ 0.40	15608 $\pm$ 300
Soil Sample-3	1497 $\pm$ 80	2346 $\pm$ 120	13.4 $\pm$ 0.1	3604 $\pm$ 200	8069 $\pm$ 200	5.08 $\pm$ 0.40	5184 $\pm$ 800
Soil Sample-4	2678 $\pm$ 100	3109 $\pm$ 600	9.02 $\pm$ 0.08	7192 $\pm$ 100	15561 $\pm$ 300	8.02 $\pm$ 0.60	11128 $\pm$ 100
Soil Sample-5	2925 $\pm$ 700	3234 $\pm$ 900	9.23 $\pm$ 0.05	6944 $\pm$ 200	15512 $\pm$ 300	9.87 $\pm$ 0.28	10586 $\pm$ 200
Soil (Mean)	4,724 $\pm$ 3400	3,518 $\pm$ 1300	12.1 $\pm$ 5.3	9,536 $\pm$ 6000	16,704 $\pm$ 7200	9.2 $\pm$ 3.9	11,111 $\pm$ 3900
Control Soil	2206 $\pm$ 60	1795 $\pm$ 60	12.4 $\pm$ 1.0	1183 $\pm$ 300	1899 $\pm$ 90	6.26 $\pm$ 0.50	185.3 $\pm$ 0.3
FAO/WHO Limit	50,000	10,000	300	20,000	30,000	60	30000

Cd-cadmium, Cr-chromium, Cu-copper, Hg-mercury, Mn-manganese, Pb-lead, Zn-zinc

WHO - World health Organization

FAO - Food and Agriculture Organization

below the detection limit for As. The recorded levels were within the FAO/WHO set limits for cassava. Similar studies of active mining sites have reported higher levels of several metals [34], including Hg in cassava [35]. Comparatively, cassava peels recorded significantly higher levels of almost all metals compared to cassava stock. The mean concentrations of metals in plantain were generally higher than those in cassava samples for almost all metals. This may be due to the general accumulation of metals in the parts of the food crop compared to the parts of the roots [36]. For all metals, the concentrations in the cassava and plantain peels were higher than recorded in the stock of each crop. This suggests the preferential accumulation of metals in the peels and husks of plantain and cassava, a trend reported in the literature for several crops [37,38]. Although this phenomenon presents huge environmental risks since peels are used in manure or as feed by animals, the accumulation of peels helps to reduce the levels of metals in edible parts, helping to reduce their direct health risk from consumption in humans.

Levels of heavy metals in soil

Metal levels were generally high in the soils of all communities sampled. Cr showed the highest levels ($\mu\text{g/kg}$) in soil samples with a range of 8,069 – 28,078 in all studied sites with a mean value of 16,704 (SD 7200 $\mu\text{g/kg}$). These values are seen as significantly high, particularly for the West African region, where metal levels are generally lower compared to the Asia/Latin American regions. However, even higher values of up to 110,000 $\mu\text{g/kg}$ and 739,500 $\mu\text{g/kg}$ have been reported by Botwe et al. (2020) and Akoto et al. (2016), respectively, from active mining sites [39,40]. Hg recorded the lowest levels in soil samples studied with a range of 8.04 – 13.4 $\mu\text{g/kg}$ and an average value of 12.1 (SD 5.3 $\mu\text{g/kg}$). Similar values (0.7 – 8 $\mu\text{g/kg}$) have been reported in the Wassa West District of the Western Region of Ghana [41]. However, significantly higher concentrations (220 – 1,750 $\mu\text{g/kg}$) have been reported in soil samples from the main mining town of Obuasi in the Ashanti region of Ghana [29]. Although Hg is found in the earth's crust and may be exposed through mining activities, elevated levels of the metal at Ghana's mining sites are mainly due to its use during gold processing from its ore. This activity is despite the commitment of Ghana as a signatory to the Minamato Convention on curbing the proliferation of mercury use in the environment. Given the nature of its use in small-scale mining in Ghana, Hg can largely evaporate from mining sites and spread to nearby communities [42].

The concentration of Zn ranged from 1497 to 9634 $\mu\text{g/kg}$ with a mean of 4,724 (SD 3,400 $\mu\text{g/kg}$). These results are significantly lower than those reported by Gyamfi et al. of 16,400 – 95,800 $\mu\text{g/kg}$ [25], Adomako et al. (14,400 – 98,300 $\mu\text{g/kg}$) and Tibu et al. (30,160 – 39,630 $\mu\text{g/kg}$) [43,44]. Generally, higher levels of Cu were recorded in soils with values ranging from 3,604 to 19,298 $\mu\text{g/kg}$ with an average value of 9,536 (SD 6,000 $\mu\text{g/kg}$). Similar to other metals, these values are generally lower than similar

studies from active mining sites reported [10,33,45]. As expected, the results of the highly toxic metals Pb, Cd, and As were relatively low, with values ranging from 2,346 to 5,670 $\mu\text{g/kg}$ for Pb, 5.08 to 15.54 $\mu\text{g/kg}$ for Cd, 5,184 to 15,608 $\mu\text{g/kg}$, respectively. As similarly observed for other metals, the concentrations recorded in this study are generally lower for some metals than those reported in other studies [46,47]. The mean concentrations of Zn, Pb, Hg, Cu, Cr, Cd, and As in the soils sampled from all abandoned mining sites were considerably higher than those obtained at the control site within the community at least 10 km from any known active site. This finding suggests that mining activities in communities have contributed to the exposure to metals and the elevated contribution. Although the concentrations were generally within suggested limits, elevated levels present significant risks to the ecosystem given that, in some cases, soils were obtained from sites that had experienced mining activities more than a decade ago. Even more significant is the exposure of metals to humans through uptake by vegetation and crops [48]. Generally, the findings of this work affirm that mining activities may have a lasting contribution to the exposure of toxic metals or metals at potentially toxic levels even years after the cessation of mining. This adverse effect may occur from exposure to metals through vegetation and uptake by crops, consumption of water and inhalation, and dermal contact through the high mobility of these metals in the environment once exposed. By their nature, the non-biodegradability of metals makes their exposure through indiscriminate mining activities a serious and persistent source of concern. However, the findings of the study are limited by the availability of abandoned sites and relevant crops and vegetation at these sites.

Conclusion

The findings from the study show the significant influence of mining on the exposure of metals in water, vegetation, crops, and soils. Compared to control samples, almost all metals studied (Zn, Pb, Hg, Cu, Cr, Cd, and As) recorded higher levels in crops, water, vegetation, and soils from abandoned mining sites and communities compared to controls or recommended limits. The study suggests that although previous mining sites and excavated soils from previous mining activities may have lower concentrations of metals, they continue to contribute to the exposure of metals in the ecosystem, particularly through their absorption in plants. These findings present considerable risks of toxicity to humans, given that, once exposed, metals do not biodegrade but become more mobile in the ecosystem with increased exposure to humans. Given the proximity of small-scale artisanal mining to human settlements, the indiscriminate mining activities and processes, and the use of toxic metals such as mercury in mining operations, the risk posed by mining activities is considerable during the life of the mining operations. Unfortunately, these risks may persist for many years, posing huge detrimental risks to humans. As a result, proper enforcement of mining restrictions and regulations is

imperative. This, along with the proper restoration of previous mining sites, will be needed to minimise human risk and protect lives in many communities in Ghana, considering the proliferation of active mining activities throughout the country.

DECLARATIONS

Ethical consideration

There were no significant ethical risks from this study. Ethics approval was obtained from the Noguchi Memorial Institute for Medical Research Institutional Review Board (Protocol# 048/17-18)

Consent to publish

All authors agreed on the content of the final paper.

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Competing Interest

None

Author contributions

The study was conceived by RA and Designed by AKC and ED. RBO, AKC and ED collected data. Analysis and data processing was led by ED and RBO. The manuscript was drafted by RBO and ED and approved by all authors.

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Availability of data

The data for this work is available upon request from the corresponding author.

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Decentralisation, informal mining, and environmental health: A political ecology perspective on Ghana's mineral wealth management

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Abstract

Background: In Ghana, a transformative shift is reshaping the management of natural resources by transferring authority from centralised bodies to local governance structures. This pivotal change aims to empower stakeholders at the grassroots level to oversee resource governance. Concurrently, efforts to formalise mining activities seek to bring regulation and structure to mining rights. This evolving institutional change has sparked intricate dynamics among multiple actors, each striving to shape institutional reforms and influence the distribution of mineral resources.

Objectives: Rooted on insights from political ecology, this study aims to profoundly examine the ramifications of decentralisation on formalisation endeavours, particularly delving into the detrimental impacts of informal mining, commonly known as galamsey in Ghana.

Methods: Focused on Dokrupe and Tinga communities, the study employed a mixed-method approach to engage with a diverse array of stakeholders, including members from water user associations, traditional leaders, gold committees, youth groups, heads of the District Assembly's sub-committees and household heads for both qualitative and quantitative data.

Results: The findings underscore the critical need to situate the adverse effects of informal artisanal mining within the broader context of stakeholders' strategic adaptations following the partial implementation of decentralisation. Notably, the reluctance to delegate power to local stakeholders in managing mineral wealth stands out, potentially fueling informal mining practices. This, in turn, worsens environmental degradation and triggers significant health crises among miners and community residents. The policy recommendations emphasised in this paper underscore the urgency of absolutely decentralised, robust environmental regulations and participatory decision-making processes.

Conclusions: The paper advocates for empowering local communities through education and engagement initiatives to foster sustainable mining practices and mitigate negative health impacts. These recommendations are crucial in steering towards more inclusive, community-driven resource governance, ultimately promoting sustainable development and healthier mining practices in Ghana's mining communities.

Keywords: Decentralisation, environmental health, galamsey, mineral wealth and political ecology

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INTRODUCTION

Since the 1970s, various international donor communities have frequently lent their support to the decentralisation of natural resource management in Ghana. The underlying belief is that decentralisation would shift governance responsibilities to local-level stakeholders and, in turn, yield a variety of favourable results, encompassing responsible mining, mine safety, reducing health risk and promoting checks and balances [1,2].

Nevertheless, it is worth noting that research on decentralisation of natural resource management primarily focuses on its structural and organisational variants while paying less attention to the actual consequences [3,4]. Consequently, this paper undertakes an examination of informal mining, also known as galamsey, in the Ghanaian context and its consequences on the environment and health of miners and the local population within the broader context of decentralisation and formalisation reforms championed by the global north. In recent times, the decentralisation and the formalisation of rights in resource management and utilisation are gaining more attention in the global south because of the negative impacts of informal

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mining practices [5,6,7]. Decentralisation refers to the transfer of control over natural resource management from a central government to a variety of local government actors [1,4]. The assumption is that shifts in rights and authority over natural resource management will augment local participation in the governance process and enhance protection from over-exploitation [8]. Consequently, the Provisional National Defence Council Law (PNDC) 207 was enacted to empower local government to grant business permits to local entrepreneurs in mining and to implement strict environmental laws [9]. Simultaneously, the Minerals and Mining Law of 1986 was passed to criminalise artisanal and small-scale mining. The reason was to promote and protect the mines of foreign multinational businesses [9,10]. Three years later (1989), three important laws affecting the mining sector were promulgated. One such law is the Provisional National Defence Council Law 218, which was enacted to begin a licence system and establish support centres across the districts to aid the formalisation of informal artisanal and small-scale mining. Section 83(a) of the Minerals and Mining Act 2006 (Act 703) also grants Ghanaians aged 18 years or more the opportunity to obtain mining licences and concessions. The advantages of formalisation of rights of informal mining, especially gold ore mining, are varied, including enabling traceability of gold ore extracted and promoting responsible mining at upstream and downstream levels to minimise the negative consequences [6,7].

There is a growing critique that the formalisation processes of informal miners are affected by high costs, bureaucracy, and perceived bias in the distribution of mining licences and concessions. This can contribute to aggravating unintended outcomes. For example, the challenges of formalisation of mining rights can force people to engage in galamsey, leading to environmental degradation and poor safety compliance. This is because their mining practices are usually not supervised for strict compliance in terms of chemical use, safety protocols and legal trading of the gold ore extracted [7,11,12]. There are also increased concerns that the revenue of informal mining can be used to promote and support various forms of crime and crime-related activities. Drawing insights from political ecology [13,14], this research investigates the implications of informal mining within the broad context of decentralisation of natural resource management, formalisation measures, and their associated institutional mechanisms. A political ecology lends a concrete analysis of power dynamics among local power-holding stakeholders, state agencies, and local miners. Political ecology helps to explain how the rules of the game that regulate resource management and use are constantly shaped within a specific historical, political-legal, and socio-economic context influenced by power relations [15]. A political ecology perspective enables the analysis of who benefits, when they benefit and who bears the brunt of the mismanagement of resources in the distribution processes [14]. In other words, the political ecology perspective can enable the analysis of the agency

of social groups in the redistribution processes occurring in decentralised natural resource management [9,15].

Against this backdrop, the paper endeavours to offer a comprehensive and nuanced understanding of the implications of informal mining on the environment and health of miners and local populations. Thus, the study asks: What strategies do stakeholders use in the management of mineral wealth? How do the strategies applied by stakeholders in managing local mineral wealth contribute to exacerbating the adverse impacts of informal mining on health, the environment, and the affected communities? How do the local communities respond to the negative effects of informal mining, and which measures do they employ to address these impacts? In this paper, two lines of arguments are presented: Firstly, the paper demonstrates that the strategies used by the diverse stakeholders in the management of the mineral wealth and the adverse consequences of informal mining are a result of Ghana's implementation of partial decentralisation. Secondly, the adverse consequences compel communities to unite against their dispossession of natural resources. The case study area of the Bole district in Ghana's Savannah region stands as a pivotal context for examining the intricate dynamics between decentralisation policies, formalisation initiatives, and the exploitation of gold ore resources.

Adam et al. [9] underscore the significance of this region in understanding how these elements interact within the mining landscape. Within Ghana's legal framework, the extraction of gold ore is profoundly shaped by a complex amalgamation of public policies, mining rights, and customary laws. This framework directly influences Ghanaians' access to small-scale mining rights, concessions, and the subsequent mining practices that unfold. In this context, the legal status of a miner holds immense sway over the nature of mining activities. Adam et al. [9] and Ntewusu [16] both elucidate this point, indicating that the legal framework dictates whether mining practices will be responsible or otherwise.

This legal framework essentially becomes the linchpin determining the legitimacy, rights, and practices surrounding gold ore extraction in Ghana. Consequently, the dynamics between decentralisation policies, formalisation endeavours, and the on-ground realities of mining practices are deeply enmeshed within this legal framework. Moreover, the Bole district's specific geography and socio-economic context further accentuate the complexities in the interplay between decentralisation, formalisation, and mining practices [16]. Understanding these dynamics within this specific locale is crucial for comprehending the broader implications and challenges inherent in the governance and management of mineral resources, particularly gold ore, in Ghana. The region serves as a microcosm that encapsulates the multifaceted relationships and influences shaping the mining landscape within the broader national and legal context. The

subsequent section provides a detailed exploration of the materials and methods employed to collect data from pertinent stakeholders, aiming to comprehend the intricate dynamics of informal mining in the communities of Dokrupe and Tinga. Section 3 unveils the intricacies of the negative impacts on miners' health, environmental degradation, and the overarching influence of informal mining on local livelihoods. Section 4 navigates the nuanced arguments presented in the paper, dissecting the implications for policy, governance, and community resilience in the face of informal mining's far-reaching impact. Finally, the conclusion encapsulates the research's significance, implications, and contributions to the discourse surrounding informal mining in these communities.

MATERIALS AND METHODS

This study utilised a mixed-method approach, integrating qualitative and quantitative methods. By combining these methodologies, the research aimed to complement the strengths of each, permitting data triangulation and validating the findings. The purposeful sampling technique was used to select Dokrupe and Tinga in the Bole district of the Savannah Region of Ghana (Figure 1) to facilitate a comprehensive understanding of the multifaceted impacts of informal mining on both the environment and human health. In Dokrupe, two traditional leaders, three gold committee executives, five members of the water user association, and 40 household heads involved in diverse livelihood activities were selected for interviews. While in

Tinga, the study meticulously selected four traditional leaders, six gold committee members, seven water user association members, 58 household heads, and five youth group members. In addition, five heads of the District Assembly's sub-committees were selected and interviewed. The selection of the diverse stakeholders in the study was not influenced by a strict statistical representation often used in purely quantitative studies. The study's flexible sampling approach was aimed at capturing a wide array of perspectives and experiences related to informal mining practices in the communities. The diverse stakeholders were interviewed from February 2019 to February 2021, with scheduled visits to the communities. The methods of data collection were key informant interviews, focus group discussions, field observation, and structured questionnaires.

The key informant interviews focused on understanding the impacts of informal mining on the environment, community health, and socio-economic conditions and observed changes over time. Moreover, the Focus Group Discussions (FGDs) session provided nuanced insights into community perceptions, experiences, and concerns regarding the effects of informal mining. Organised in one of the classrooms at the community Junior High School, the FGDs fostered interactive dialogues among the diverse set of stakeholders because of the neutral space provided. Furthermore, evidence was collected through meticulous observations of the miners to understand the direct consequences of informal mining activities on water bodies, ecosystems, and the surrounding environment. This approach was pivotal in substantiating the qualitative data.

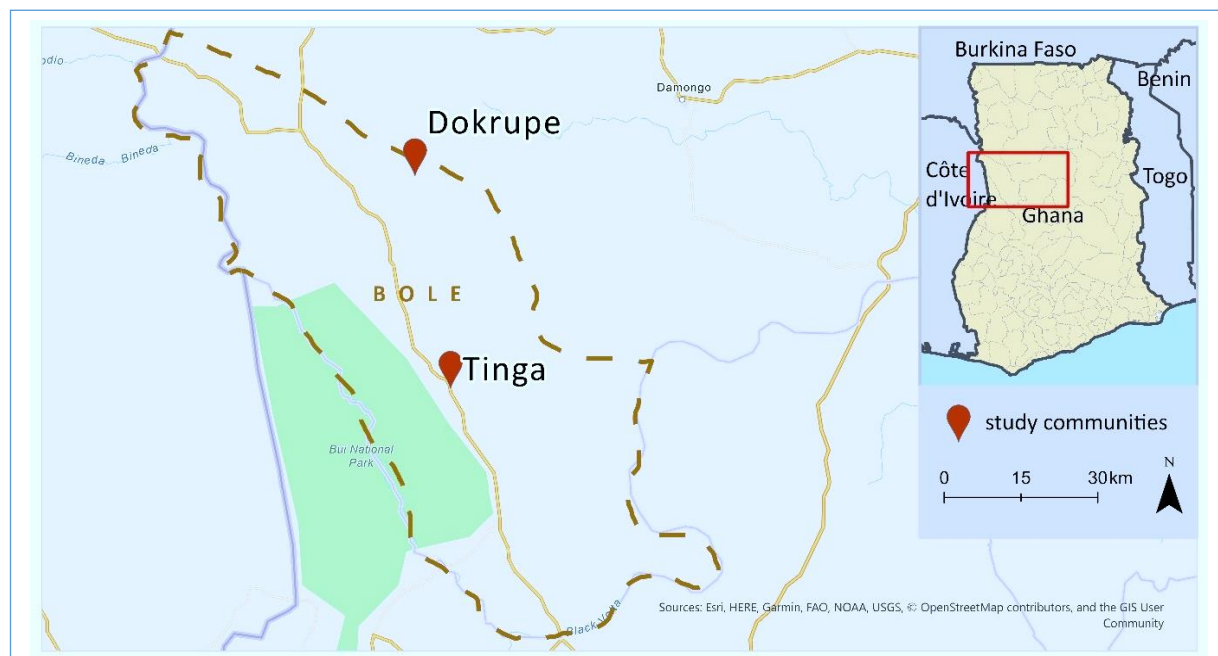


Figure 1. Location of the two study communities in Bole administrative map

A structured questionnaire was designed to gather quantitative data to facilitate statistical analysis. The use of multiple data collection methods was to enhance the triangulation of data and to ensure robustness, credibility, and depth in the findings. On the one hand, qualitative interviews were recorded in field notebooks, which culminated in codes and were organised into themes for the in-depth analysis of the data. The quantitative data, on the other hand, were entered into Microsoft Excel (Microsoft 365, 2021) for frequency and percentage analysis. The data from both the qualitative and quantitative methods were integrated to facilitate a more comprehensive picture of the study findings. For example, while the qualitative data are presented in narrative and descriptive forms and backed with quotations, the quantitative data were presented to indicate the prevalence quantum of the responses.

RESULTS

This section presents the stakeholders' strategies and the formal and informal rules involved in the local management of mineral wealth. The stakeholders include the district assembly, the Minerals Commission, traditional leaders, gold ore committees, and informal artisanal miners. The section also presents a summary of the findings in Table 1. The establishment of the district assembly under PNDCL 207 was intended, among others, to empower it to oversee responsible mining practices through the issuance of business permits and monitoring [9,10]. Yet, a reluctance to decentralise authority has hindered the effective enforcement of environmental regulations within the local communities. Insights from the heads of the District Assembly's sub-committees emphasise the reluctance of local government authorities to devolve power to enforce environmental regulations in local communities. This hindrance perpetuates a cycle where environmental governance remains compromised, negatively impacting the community's ability to ensure responsible mining. The responses of the heads of the sub-committee in the District Assembly suggest that the Assembly is looking up to the Minerals Commission to ensure responsible mining in the local communities. This perception seems to suggest a lack

of coordination between the District Assembly and the Minerals Commission.

The Minerals Commission holds a crucial position in the management of mineral wealth in the local communities. It is mandated to ensure responsible mining practices, prevent gold ore smuggling, and supervise the processes of license and mining concessions to qualified individuals and entities [9]. However, challenges, including inadequate staff, logistics and equipment, impede the smooth operations of the Minerals Commission. These challenges affect the Commission's ability to supervise and monitor gold ore mining. It also finds it hard to provide adequate mining support to legitimate operators. The survey conducted in 2019 shows that 98% of local miners depend on traditional authorities and their structures to participate in informal mining. In Ghana, the Land Act 2020 (Act 1036), pursuant to clause 8 of Article 36 of the Constitution, mandates traditional leaders to manage stool, skin, or family land. As such, section 13(2) of Act 1036 states that "A chief, tendana, clan head, family head or any other authority in charge of the management of stool or skin, or clan or family land, is a fiduciary charged with the obligation to discharge the management function for the benefit of the stool or skin, or clan or family concerned and is accountable as a fiduciary". In the local communities in Bole, traditional chiefs are responsible for granting surface land to individuals [17], although they recognise that the state has the prerogative to issue mining concessions to Ghanaians for small-scale mining. However, the absence of the Minerals Commission grants traditional chiefs an opportunity to give illegal permits for the extraction of gold ore. The traditional chiefs strategically allow local structures like the gold committees to evolve to manage the distribution of mining permits. In addition, they also grant miners permits to cut logs and use the available water resources to support mining activities.

The dominance of the gold ore committees and their potential oversight of informal mining activities cannot be overemphasised. The committees, comprising influential community members closely associated with traditional leaders, wield significant authority in shaping informal

Table 1. Roles, challenges, and interactions of stakeholders in mineral wealth management

Stakeholders	Roles	Challenges/issues	Interactions/relationships
District Assembly	Oversight through business permits and monitoring.	Reluctance in devolving authority impacting environmental governance.	Lack of coordination with the Minerals Commission.
Minerals Commission	Overseeing mining operations, mitigating environmental impacts, licence issuance	Inadequate staff, logistics, and equipment affecting operations.	Weak relationship with informal miners
Traditional leaders	Granting surface land rights, supervising mining permits, providing resources	Absence of Minerals Commission in the communities allows traditional leaders to gain control.	Collaboration with gold mining committees for supervision.
Gold mining committee	Authority in shaping mining activities, collecting fees/taxes, providing support.	Considerable power in mining activities, symbiotic relationship with miners.	Preference to operate under traditional authorities for local support.

mining activities. The gold committees also maintain a symbiotic relationship with the miners. The committees grant loans to distressed miners, rent mining equipment and tools to under-resourced miners, arrange buyers, and provide escort security for the transportation of unrefined gold to southern Ghana, especially Kumasi. The committee's statement is as follows: "There is no doubt that we hold considerable power in the mining space. We are only accountable to the traditional leadership and are mandated to ensure that every miner is registered and pays appropriate fees for the development of the communities. We also provide financial and security support for people in need in the community" (Executive member of the gold committee in Tinga, FGD, 23.3.2019).

Over 84% of informal miners perceive mining licences and concessions as structured along patrimonial lines, favouring individuals with political or financial clout. The expression below succinctly encapsulates the perception of a local miner: "I am 20 years old and qualify to possess a mining licence. Yet, the high cost of licence processes is a key obstacle. I feel that the system silently favours people who have political and family connections with the Minerals Commission, leaving some of us without any influence and burdened by excessive fees such as the payment of bribes. This inflexibility in licensing procedures is stifling our ambitions for conducting legitimate operations" (Local miner in Dokrupe, FGD, 18.5.2019). The financial constraints and perceived favouritism challenge the fairness and equity of the formalisation process as stated in the Minerals and Mining Act 2006 (Act 703).

Nearly 92% of the local miners reported that the Minerals Commission is understaffed to provide them with the necessary support services they require. As a result, the majority of local miners opt to operate under traditional leadership and the gold committees. According to a local

miner in Dokrupe, the traditional leaders and gold committees are "their life jacket in the ocean". Thus, the findings show that most of the stakeholders involved in the management of mineral wealth have failed, leading to the hijacking of mineral resources by traditional leaders and their allied structures (see Table 1). This outcome results in environmental challenges, which negatively affect local communities, miners, and their families. The next section presents the effects of informal mining in the local communities.

Effects of informal mining

This section shows how the aftermaths of informal gold ore mining extend far beyond mere environmental damage and illustrates that the effects of galamsey seep into the local communities and corrode their health, livelihoods, and ecosystems. This section also highlights both the shared and differing impacts of informal mining in Table 2. The findings show that the negative impact of mining is multifaceted. The findings demonstrate that the hazardous conditions prevalent in the mining sites, such as lack of safety protocols and proper infrastructure, significantly heighten the risk of accidents and injuries. Some of the miners indicate that the collapse of rudimentary tunnels and accidents involving heavy machinery are regular occurrences, leading to severe injuries of over 37 miners and even four fatalities of miners in Dokrupe.

The lack of proper ventilation in the mine and exposure to harmful substances poses significant health risks to these miners. Also, the rise of galamsey has become a breeding ground for the spread of several types of sexually transmitted diseases. The transient nature of the workforce, coupled with limited access to healthcare and preventive measures, has fostered a rapid transmission of sexually transmitted infections among 83 people in Dokrupe over the two-year study period. As miners move in and out of the area, this mobility has inadvertently contributed to the

Table 2. Comparative impacts of informal mining on Dokrupe and Tinga communities

Impacts	Dokrupe	Tinga
Health impacts	Higher incidence of miner injuries and illnesses due to accidents and exposure to harmful substances.	Miners suffer similar dangers and health issues but comparatively lesser intensity.
	High reports of sexually transmitted diseases	Concern for loss of herbal resources but less emphasis compared to Dokrupe.
	Substantial loss of traditional medicinal herbs.	
Environmental impacts	Severe water pollution, deforestation, contamination with toxic substances	Similar severe water pollution, deforestation, contamination.
	Reduced water usage for daily activities due to pollution concerns.	More prominent water scarcity issues affecting various aspects of daily life.
Livelihood impacts	Reduced agricultural yields.	High death rates of fish.
	High livestock mortality rates.	Decline in fishing, affecting nutrition and income
Economic impacts	Businesses growth, agricultural productivity, and potential tourism affected significantly	Economic strain due to illness but not as severe; less impact on potential economic activities.

unchecked dissemination of sexually transmitted diseases, posing a significant health risk to both miners and the downstream stakeholders. Moreover, informal mining results in the colossal destruction of the vegetative cover, which is a major source of local herbs for the treatment of many diseases, such as stroke, ulcer, miscarriage, etc., by herbalists. The following quotation provides a deeper understanding of this dynamic: “Galamsey miners have disregarded the need to preserve our traditions and protect the vegetative cover, which is relied on by herbalists and traditional healers like me for treating serious spiritual health problems. Because of this, I now cover long distances to get certain essential herbs for the treatment of epilepsy, sexually transmitted diseases, etc.” (Herbalist in Dokrupe, FGD, 26.2.2020). However, in Tinga, some herbalists have not expressed much concern about the loss of essential herbs in the surrounding environment. The reason is that informal mining is less pervasive in Tinga compared to Dokrupe, which surrounds mining sites (Table 2). The people of Dokrupe face risks associated with the environmental consequences of informal mining. The release of sediment from mining sites, the runoff of acid from mines and the discharge of highly toxic substances such as mercury, cyanide, cadmium, lead, and arsenic [18,19] infiltrate the environment and contaminate the diverse water sources, including underground water. These contaminants have detrimental effects not only on the environment but also endanger the health of local residents who rely on water bodies for daily use. Long-term exposure to these toxic substances contributes to chronic health issues, including skin lesions, cancer, vascular diseases, and kidney and reproductive disorders, impacting the quality of life for these individuals [20,21,22,23].

According to Cobbina et al.[21], the amounts of heavy metals in drinking water in Tinga are above the World Health Organization’s recommended limits [24]. A poignant quotation capturing the dire consequences of informal mining came from a local miner deeply affected by the hazards of mining: “Every day, we fear for our lives working in these conditions. Accidents are a constant threat, and the poisonous substances in the water affect not

just us miners but our families who rely on these resources. We are trapped between survival and endangerment, trying to eke out a living while risking our health and lives” (Local miner in Tinga, FGD, 11.5.2020). The distressing trend of a large number of community members falling sick due to exposure to these substances illustrates the direct link between environmental negligence and deteriorating health. The toll of illnesses also redefines relationships, urging the few healthy to rally more around care and support. Over 70% of household heads in the 2020 survey conducted showed that women reported going to fetch water from far places for sick people because of the transformation of the community’s pristine streams into polluted havens. Therefore, many households are compelled to reduce the consumption of water for domestic use by a significant amount (Woman in Tinga, FGD, 11.5.2020). Besides, 86% of the households in the 2020 survey reported that the aquatic resources, especially fish, which are used to sustain the households’ livelihood and nutrition, suffered a severe decline.

In a FGD, 7 out of 8 fishermen indicated that they currently do not harvest enough fish as compared to 20 years ago. They sometimes catch less than ten fish in over 2 hours of fishing. Some fishermen reported that the streams are sometimes flooded with dead fish during the rainy season when the runoff of acid from mines into the streams intensifies. Also, many livestock keepers lamented that the mortality rates of their livestock have increased due to the consumption of polluted water sources. A livestock keeper laments that: “I am now experiencing higher mortality rates than before. I used to experience 1 or 2 deaths of livestock in a year some 16 years ago. But last year alone, I experienced six deaths of sheep and five deaths of goats. This has reduced my income level and simultaneously increased my vulnerability to food insecurity” (Widow livestock keeper, 23.4.2020). Also, a 2020 survey indicates that over 3,000 people in both Dokrupe and Tinga often consume unwholesome vegetables irrigated from polluted water sources. Thus, the negative impacts of galamsey have serious implications for the local economy. One example is presented below: “The detrimental impact of the high

Table 3. Comparison of community responses against informal mining

Social response	Dokrupe	Tinga
Environmental protection advocacy	Less organized collective resistance.	More organized resistance The community seeks stricter regulations and enforcement. Government workers to vacate post if actions are not implemented to reduce the negative impacts of mining.
Community mobilization	Community mobilization is often aimed at supporting informal mining.	Government workers organize public meetings and forums. Government workers provide support to injured and sick people affected by mining activities.

Source: Field interviews, 2019-2021

number of illnesses has profoundly crippled our local economy. The illness leads to hospital admissions of miners and their families, which makes the community's economic engine slow and suffocate. Business operators are struggling, and labour for agricultural activities is reducing because people have to shift roles to take care of sick people. This generates a cycle which reduces economic activities and wanes income level, leaving us grappling with hardships we never anticipated" (Retired educationist in Dorku, FGD, 5.2.2020).

In this section, the responses of the communities against informal mining are presented. In light of the devastating effects of informal mining, a segment of the population in Tinga has displayed a blend of urgency and resilience, calling for immediate action and stricter regulations to confront the dire environmental degradation and health issues. The demand for change stems from a profound need to safeguard not only the environment but also the health and sustenance of the community. The voice of the community, especially farmers dispossessed of their farmlands in Tinga who experience the brunt of galamsey, echoes a resolute stand against the government's inability to tackle the menace of environmental degradation and health concerns caused by informal mining. The quotation below encapsulates the feelings of local residents: "Faced with the dire consequences of mining activities, we are united to demand immediate action to safeguard our water resources and farmlands. We stand resolute and call for stringent regulations to prevent further harm in order to ensure long-term resource preservation" (Farmer in Tinga, FGD, 28.2.2021).

The community's concerted efforts reflect a shared commitment to resist further environmental crises. Consequently, government workers like nurses and teachers have supported and sponsored public meetings and forums to galvanise community support to demonstrate against the stakeholders involved in promoting informal mining [25]. These government workers have also threatened to vacate posts if immediate actions are not implemented to minimise the negative effects of informal mining (Table 3). The quotation below throws more light on the dynamic: "We are urging for sustainable practices that preserve our vegetative cover, farmlands, and water bodies, crucial for our survival and the generations yet to come. We can no longer stay quiet and watch the young contract sexually transmitted diseases such as Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome", which becomes a burden on all of us. The relatives of those who fall sick approach us for money to pay for medical bills or buy food for the sick people" (Teacher in Tinga, Interview, 28.2.2021). However, the findings in Dorku show that the gold committee supports informal mining and actively undertakes activities to make the operation of informal mining conducive. These include sponsoring the repair of broken bridges and culverts and bad roads linking the community and mining sites.

DISCUSSION

The empirical findings weave a complex narrative, which demonstrates that the state custodians of mineral wealth management fade, fostering an environment where informal mining thrives, perpetuating an escalating environmental crisis. This outcome jeopardises the health of miners and local communities contrary to the goal of decentralisation reform [1,2,26]. The legal framework of managing mineral resources entrusts the Minerals Commission (e.g., Act 703) with the critical task of mitigating environmental impacts and regulating mining operations. However, the Commission faces a myriad of challenges, including limited staff, equipment, and logistics. For example, limited resources hamper the Commission's capacity to effectively enforce responsible mining practices, exacerbating the proliferation of unregulated mining activities. This resource deficit pushes local miners towards informal structures such as traditional authorities and gold committees, inadvertently legitimising informal mining within local jurisdictions and perpetuating environmental and health hazards for the communities.

The District Assembly, initially positioned to oversee responsible mining practices, grapples with a glaring reluctance to decentralise authority [9,4]. This hesitation translates into weakened enforcement of crucial environmental regulations at local levels, creating a void in governance that allows informal mining to flourish virtually unchecked [5,9,28,29,30]. Hence, traditional leaders, leveraging the absence of formal oversight, wield significant influence over mineral rights and permits through gold committees. This effectively legitimises informal mining within local jurisdictions but deepens the environmental and health implications faced by the communities [10,27]. The absence of formal oversight leads to a skewed power balance [13], allowing traditional leaders to benefit from mineral wealth without adequate scrutiny or regulation, further perpetuating the cycle of unregulated mining practices. The challenges encountered by informal miners in obtaining licenses, perceived as biased and favouring individuals with political or financial influence, underscore systemic inequities within the formalisation process [6,7,11,14]. This disparity further alienates miners from formal structures, compelling them to rely on informal avenues for support and legitimisation of their mining activities. This stark divide between formal and informal mining sectors amplifies structural flaws within the regulatory framework, exacerbating environmental and health risks such as sexually transmitted diseases, injuries, and death [3,4].

Amidst this complex web of challenges, the community's unified call for change emerges as a beacon of resilience and hope. Residents, burdened by the devastating consequences of informal mining, stand united in demanding immediate action and stringent regulations to protect their environment and health. This grassroots movement [15,25], bolstered by the alignment of

government workers with the community (e.g., Tinga), underscores a collective determination to combat irresponsible mining practices. The communal outcry illustrates a profound need for effective policy interventions to bridge the gaps in oversight and regulation. The urgency for stringent environmental policies and robust enforcement mechanisms becomes palpable in the face of escalating environmental degradation and health risks associated with informal mining. The rallying cry from the community serves as a testament to the imperative for inclusive and proactive governance structures that prioritise the well-being of miners and local residents. The interplay between formal and informal structures within the mining sector highlights the systemic challenges that must be addressed. The intricate web of stakeholders, each with their vested interests, underscores the need for comprehensive policies that foster responsible mining practices while safeguarding the environment and community health. The findings spotlight the urgency for collaborative efforts between government bodies, local authorities, and communities to devise and implement effective strategies that mitigate the adverse impacts of informal mining on both the environment and public health.

Conclusion

This study delves deeply into the complex interplay between decentralisation in natural resource management, the formalisation process, and the detrimental impacts of informal mining on miners' health, local populations, and the environment. Grounded on the political ecology perspective, this study sheds light on the intricate power dynamics and structural inequalities inherent in the governance of mineral wealth. Through a mixed-method approach encompassing surveys, interviews, focus group discussions, and observations, the research methodology meticulously captured diverse insights into the intricate landscape of informal mining.

The analysis of the collected data vividly illustrates the collective failure of stakeholders to supervise and monitor responsible mining. This unintended outcome should be understood within the context of Ghana's implementation of partial decentralisation. The failure to implement an effective decentralisation reform contributes to the cycle of environmental degradation and compromises the health of both miners and local communities. Against this backdrop, comprehensive decentralisation is a pivotal solution that will empower local authorities to exert more effective oversight and enforce stringent environmental policies through their local structures. Hence, strengthening local governance structures is crucial for ensuring responsible mining practices and robust enforcement of environmental regulations. Simultaneously, the formalisation process demands streamlined licensing procedures, reduced financial barriers, and equitable access to mining rights. These initiatives serve as catalysts in motivating miners to transition from informal to formal practices, consequently mitigating environmental damage and health risks.

The policy recommendations outlined in this paper emphasise the urgency of decentralised oversight, robust environmental regulation, and participatory decision-making processes. Empowering local communities through education and engagement initiatives can pave the way for sustainable mining practices and enhance environmental stewardship. The paper contributes to unravelling the intricate relationships between stakeholders, state agencies, and local communities, emphasising the imperative for more equitable and inclusive policies within the mining sector. Looking ahead, future research could explore the broader socio-economic implications of environmental degradation caused by informal mining. Investigating long-term economic sustainability and delving into the effectiveness of community-driven initiatives would provide invaluable insights into sustainable solutions, bridging the gap between policy and grassroots perspectives.

DECLARATION

Ethical consideration

The study adhered to international guidelines such as the Institutional Review Board of the University for Development Studies.

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The author declares that there is no conflict of interest regarding the publication of this article.

Author contribution

None

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Availability of data

Data for this work is available upon request to the author.

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Decoding the persistence of gamamsey in Ghana: The meta-contradictions of neutered law

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Abstract

Background: There is a lack of consensus on the appropriate regime for socio-political regulations regarding gamamsey. In this context, people with unrestrained pecuniary ambitions defy or evade laws enacted to curb gamamsey, thereby rendering them neutered even when violently enforced.

Objectives: This study aimed to demonstrate that the failure of the Government of Ghana to curtail gamamsey is due to the clash of ethnic group customs and national laws, thereby generating a meta-contradiction of governance principles in gamamsey enclaves.

Methods: The study was framed by the notion of the contact zone, namely the coexistence of different principles of socio-political regulation. Areas with gamamsey are unstable contact zones of anomie, and those without them are stable synonymic contact zones. The study was qualitative ethnographic research based on primary data generated from individual interviews and focused group discussions with respondents recruited through a chain-link strategy in the communities of Akyem Asunafo and Akyem Kwabeng in the Eastern Region of Ghana.

Results: Akyem Kwabeng demonstrated the trait of an unstable anomic contact zone with its relatively weak customary norms. It was a gamamsey enclave with a destroyed ecology. This study also used secondary information on Tanchara in the Upper West Region. Akyem Asunafo is found to be a stable synonymic contact zone, upholds traditional principles of governance, has no gamamsey, and its ecology is pristine. Conversely, Tanchara, an unstable contact zone, used its customary norms to stem gamamsey and protect its environment.

Conclusions: It will be prudent for the GoG to acknowledge the superior eco-regulatory capacity of chiefs and norms of traditional eco-governance and facilitate the conclusion of Green Social Contracts (GSCs) rooted in customary principles of ecological governance in gamamsey enclaves.

Keywords: Gamamsey, contact zone, synnomie, anomie, meta-contradiction, neutered law, Ghana

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INTRODUCTION

All efforts by the Government of Ghana (GoG) since 1989 to stop gamamsey (illegal gold mining) have failed. Indeed, gamamsey has thrived and increased in scope from a small-scale endeavour to a medium-scale activity with historically unprecedented negative environmental consequences [1]. Conventional perspectives attribute the persistence of gamamsey to factors such as corruption and lack of political will [2]. This study, inspired by Peter Ekeh [3], articulates a contrary position that factors such as corruption and lack of political will, rather than being causative factors of gamamsey, are the symptoms of a clash of the differing philosophies of ethnic group customary norms and the

sovereign laws of the Ghanaian state. The governing principles of ethnic groups are rooted in the philosophy of holism [4]: the principle that the universe understood as a system of balanced interdependence between sacred and secular beings, must not be disrupted by human ambition. With holism, the norms (or laws) governing human ambition, rights, and obligations are calibrated to maintain the ideal of normatively balanced interdependence with all the other entities making up the universe. As such, holism thrives on two types of inclusive power: power-to and power-with. While power-with enacts solidarity-based communal actions, power-to enables the attainment of collective aspirations. Government, on the other hand, as a sovereign institution of the state, functions with exclusive power-over: authority expressed through coercively framed law [5]. Hence power-with and power-to are functionally different from and normatively in conflict with power-over.

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Efforts by the GoG since 1957 to project its power-over in all spheres of national life, including regulating small-scale gold mining, have often clashed with the customs of ethnic groups and, in the process, generated meta-contradictions of anomie [6] epitomised by the loosening of social cohesion often manifesting as ineffective regulation of human conduct. In contexts of matured meta-contradictions of anomie, there is no sense of legality or illegality since normative consensus, the necessary and sufficient condition to guide the framing and procedures to define acceptable and unacceptable human conduct, does not exist. In such a context, any attempt to impose externally framed legal regimes will be resisted or contested since people will only voluntarily submit to the dictates of law if its ethical basis aligns with their worldview(s) or are participants in its framing as co-creators. Resisted or contested laws are ‘paper tiger’ or neutered laws that can only be ineffectively enforced through coercion or violence [7]. One gets a sense of the neutered laws governing small-scale mining in Ghana from the wording of official and private statements such as “the fight against gamamsey”. Other expressions emblematic of neutered laws on gamamsey include; “The government intends to crack or clamp down and wage relentless war or calls for a shoot-to-kill policy” [8].

MATERIALS AND METHODS

This study is a qualitative ethnographic study by the Akyem Asunafo and Akyem Kwabeng Ghana Mining Research Group and the University of York, UK [9]. Akyem Asunafo and Akyem Kwabeng were chosen because even though they are all located (22.4 km apart) in one of Ghana’s most active zones of gamamsey [10], Akyem Asunafo has no experience with gamamsey, but Akyem Kwabeng is an active enclave of illegal mining. The study’s respondents were recruited with a two-stage chain-link recruitment strategy, an approach that does not require a pre-designated sampling population size. The first stage involved the non-probability recruitment of an Assemblyman in Akyem Asunafo and a Municipal Chief Executive in Akyem Kwabeng. The second stage involved the first-stage respondents recommending subsequent participants and/or how to reach them. The data used in this study was extracted from the responses of about 70 individuals comprising gamamsey workers or entrepreneurs, government security agents, officials, and political actors. It also includes responses from focus group interviews involving three groups of gamamsey miners. The study also uses secondary information from the gamamsey enclaves of Tanchara in Lawra (Upper West Region of Ghana) and is based on a deductive content analysis of findings.

Theoretical Framework

A contact zone is a socio-political context where different norms of governance co-exist. Contact zones may either be stable, contexts of synnomie (i.e. when different norms are consciously programmed to work in sync), or unstable and anomic (i.e. dissimilar norms clashing in opposition to each other). Unstable and anomic contact zones are prone to

crisis due to a lack of consensus on the principles of socio-political organisation [11] and hence exhibit risks of liminality: a transitional unregulated “free for all” situation where people engage in self-seeking behaviours and do not voluntarily submit to externally imposed controls [12]. If people feel entrapped such that they are unable to completely escape external controls, they resort to active subversion to reduce its effectiveness. Ultimately, risks of liminality develop under conditions of weak or absent government authority [13]. The arguments in this study are informed by Margaret Scotford Archer’s [14] idea of morphogenetic critical realism, which suggests that the internal dynamic(s) of society can be efficiently interrogated only when its superficial elements, such as law, culture, and myth, are accounted for. Morphogenetic social phenomena are context-dependent and locale-specific. Archer elaborates morphogenesis as (i) structural conditioning, (ii) social interaction, and (iii) structural elaboration. Structural conditioning defines the permissible limits of individual ambition. Social interaction maps the pattern of transactions individuals engage in. Finally, structural elaboration is the combination of structural conditioning and social interaction. Hence, it depicts the footprint of the two tendencies. The idea of morphogenetic critical realism is used in the context of this study to examine how the principles of ethnic group holism and the sovereign power of the GoG, either operating separately or together, engender gamamsey.

RESULTS

Akyem Asunafo

During a focus group discussion with the community’s Queen Mother and her Council of Elders, they noted that they uphold an ancestral admonition to despise avarice. Considering that gold is culturally regarded as a source of greed, its mining in all forms, whether GoG-sanctioned or gamamsey, is opposed. They also mentioned that the land is held in trust for their ancestors and future generations, and they will be held accountable for their stewardship. Consequently, they preferred not to offend their forebearers by yielding to the pecuniary temptations of gold. They explained further that they experienced nightmares whenever gold mining proposals from the GoG or gamamsey entrepreneurs were presented to their community, and so they have learnt to be content with their farming incomes. The community’s resistance to mining was confirmed by an official of the Minerals Commission, who noted that even though the community is rich in quartz reef gold deposits, it has opposed all efforts over three years to be included in the GoG’s Community Mining Programme [9]. Evidence of the environmental dividend from the posture of Akyem Asunafo was discernible from the pristine ecology of the Esubone River, a tributary of River Pra, which flows through the community (Figure 1).

Akyem Kwabeng

In a focus group discussion, respondents said that the Kwabeng Stool of the Gyaase Division of the Akyem



Figure 1. Esubone River flowing through Akyem Asunafo showing pristine characteristics devoid of pollution

Abuakwa Paramourty fought wars over centuries to secure their land. Given this, they see no reason why Government of Ghana appointees will issue licenses to strangers to appropriate their land for gold mining. Hence, rather than sitting aloof for this to happen, they decided to give out land to gold miners on their terms. When questioned whether, per their statements, they were not engaging in illegal actions or intended to do so, they responded that the question must be directed at the GoG since even the British colonial government, which had all the power to usurp their land, did not do so. They added that in the broader scheme of things, the fact that the GoG used its laws to undermine their land ownership rights made it guilty of illegality. Again, regarding the question of whether they have either petitioned, sought to negotiate, or dialogued with the GoG over their concerns, they responded that any effort in such a manner would be akin to abdicating their customary responsibilities or birthright.

Another respondent testified that despite the GoG's mitigation efforts, galamsey has persisted due to the collusion of government law enforcement officials, landowners, and galamsey entrepreneurs. The respondent noted an instance where a registered gold mining firm contracted and protected galamsey workers to mine on its concessions and then bought the gold mined at less than one-fourth of the price prevailing on the open market. Among others, the private firm justified the price it paid to its galamsey miners with the excuse that it would use the deduction for land reclamation even though it did not. Galamsey miners, in a focused group discussion, expressed

the view that even though they were not happy with the environmental destruction caused by galamsey, they had no choice but to engage in it. They reasoned that they were unable to access their farms, especially during the rainy season, due to dangers posed by mining pits. Elaborating further, they noted that when galamsey entrepreneurs move into a farming area and make initial offers to landowners or users, those who hesitated or declined to accept such offers would eventually not be able to access their farms when mining begins and hence are compelled to unwillingly give out their farmland at a lower compensation rate. Hence, all (farm) landowners have learned to accept initial offers.

This set of respondents also testified that since farming is no longer a viable economic venture, they have pooled funds to purchase metal detectors to form a metal detector galamsey group [10] and that they were in negotiations with the Local Assembly to have their machines/group registered and agree on a tax regime. They revealed that most male workers employed by galamsey entrepreneurs also doubled as freelance metal detector miners who are contracted to prospect for gold on farms and in homes with a prior gold sale agreement formula as follows: one-fourth for the owner of the metal detector, one fourth for the metal detector, one fourth for the contractor of the metal detector service and one fourth for the operator of the metal detector if he is not the owner. The members of the metal detector galamsey group also engaged in what they call *kolikoli*: the search for gold in abandoned pits or tailings. To the question of whether they were aware that galamsey is a crime, they responded in the affirmative but added that it



Fig. 2: Birim River showing muddy colouration, and a galamsey site characterized by muddywater-filled pits (insert) in Akyem Kwabeng

was a risk-free activity since they were always rescued with the help of their employees and the owners of the land on which they mine. According to them, galamsey miners are only harassed and detained by law enforcement agents when such help is delayed. The pattern of responses shows that GoG's efforts to regulate gold mining have not deterred individuals from pursuing self-centred pecuniary interests and security against the dictates of national law. As anticipated by the concept of the tragedy of the commons [11] and empirically evident at the time of the study in the polluted Birim River, a tributary of River Pra like Esubone (Figure 2), unregulated profiteering from illegal mining had already resulted in extensive environmental destruction.

Tanchara

In 2009, the Chief and Tengansob [12] of Tanchara fought off efforts by the GoG to grant prospecting rights to Azumah Resources Limited (ARL), an Australian gold mining firm, without the consent of the community. The ARL's presence in the community triggered an influx of Galamsey entrepreneurs, a development perceived by the Chief and his governing council as a threat to the community's sacred groves. In collaboration with the Centre for Indigenous Knowledge and Organizational Development (CIKOD) [13], an NGO, the community mounted a multi-pronged resistance strategy through, for example, radio show discussions and durbars [14]. The Tengansob is reported to have noted that "our sacred groves

have been here since ancient times. Nobody in our community has ever cut down one sacred tree, and we continue this tradition" [15]. While insisting that the GoG respect the community's sacred heritage, the Tanchara people demanded a "free, prior and informed consent with regard to all resources in the community through established traditional law and governance structure", demanding that the EPA [16], the Minerals Commission, and shareholders of Azumah Resources should freeze or suspend all transaction until the community is assured that the 70 affected sacred groves and other potentially affected sites are not damaged and that Azumah Resources put in place pragmatic measures that will facilitate a win-win situation for the environment, the communities, and the company [17].

Tanchara backed its demands with Article 257 (3) of the 1992 constitution, which states, inter alia, that all lands in the Northern, Upper East, and Upper West Regions of Ghana in the custody of the President revert to its indigenous owners after the inception of the Fourth Republic. With the help of the CIKOD, Tanchara drew up a Biocultural Community Protocol (BCP) and a Community-led Health Impact Assessment Tool (CHIAT) to document the impact of gold mining on sacred groves and public health. The BCP and the CHIAT were subsequently presented to the Paramount Chief of Lawra and his Traditional Council, who called on the people of

Tanchara to evict all galamsey miners attracted by the ARL's prospecting activities. Having witnessed the heightened activism that the BCP and CHIAT engendered, the ARL suspended its mining ambitions [24]. Consequently, the Tanchara experience informed the creation of the Upper West Coalition on Mining based on customary regimes of environmental governance [25].

DISCUSSION

The three communities of Akyem Asunafo, Tanchara, and Akyem Kwabeng together represent a spectrum of contact zones. While Akyem Asunafo, one extreme of the spectrum, is in a stable condition of synnomie and demonstrates the regulatory efficacy of customary norms in a pure form, Akyem Kwabeng, the opposite extreme of the spectrum, is an anomic zone of liminal crisis and, as such, is marked by neutered law and lax customary regulation. Tanchara, located between the two extremes of Akyem Asunafo and Akyem Kwabeng, is a stable contact zone of synchronised customary norms and national mining law, with the regulatory power of customs being relatively stronger. Consequently, while the lack of contested regulatory norms in Akyem Asunafo has preserved its ecological integrity, Tanchara, through the process of contesting the regulatory power of the GoG, has developed a model of ecological governance expressed as a philosophical antithesis to that of the state, which has become a model for the Upper West Region of Ghana. In Akyem Kwabeng, efforts by the GoG to operationalise its power to grant gold mining rights by the President, the trustee of minerals in Ghana, [26] led to disruptive consequences since the GoG's gold mining principles contradict the customary notions of land tenure, which defines land beyond the terra firma solid earth to include minerals and rivers and prohibits private ownership [27]. Against this background, the GoG's power to grant gold mining rights, from the perspective of customary norms of land tenure, counts as an illegal expropriation of land.

Albert O. Hirschman [28] argues that when actors face situations they perceive to be threatening, such as power-over pressures, they exit or evade danger by secretly forming counter-alliances as a resistance strategy. The testaments of the Akyem Kwabeng respondents can, therefore, be understood as efforts to evade or reduce the corrosive effects of the GoG's power over them. Again, recalling Archer's morphogenetic critical realism, the inability of the GoG to regulate gold mining in Akyem Kwabeng, given the uncooperative and resistant posture of the community, has created a power vacuum allowing government agents (e.g. law enforcement officials), vulnerable people (evicted farmers) and entrepreneurs to cunningly exploit the resulting governance crisis to engage in galamsey. The social interaction structure of all the entities mentioned is defined solely by an unbridled quest for monetary gain and security. The environmental degradation of Akyem Kwabeng is the structural elaboration of the combined effect of the structural

condition of governance crisis and social relations defined by the quest for economic security.

Conclusion

The cases of Akyem Asunafo, Tanchara, and Akyem Kwabeng show that the paradox of the persistence of galamsey, despite decades-old government coercive regulation, can best be resolved beyond curtailing corruption and enhancing "political will" as conventionally suggested by scholars. With the aid of the theory of contact zone and the methodology of morphogenetic critical realism, this study postulates that galamsey and its negative environmental effects are the norm in contexts with high government regulatory presence and lax customary authority. This is so because the government's enforcement of coercive power-over laws contradicts the power-with and power-to customary norms of traditional institutions under the auspices of chiefs, who consequently adopt a non-cooperative posture with the GoG. Therefore, the law in such contexts is neutered and has no regulatory effect. The experiences of Akyem Asunafo and Tanchara demonstrate that customary norms of environmental governance, without doubt, are worthy of being considered superior regulatory mechanisms. As such, chiefs, being fiduciary guardians of the said regimes, count as actors whose attitude can either make or unmake the effectiveness of any government initiative.

The GoG's efforts to continuously deploy its legal coercive powers and institutions in the name of the rule of law to curtail galamsey without the support of chiefs is therefore futile. Given this, it will be prudent for the GoG to acknowledge the superior eco-regulatory capacity of chiefs and norms of traditional eco-governance and facilitate the conclusion of Green Social Contracts (GSCs) rooted in customary principles of ecological governance in galamsey enclaves. As a first step, by way of a goodwill gesture, the GoG ought to shed its excessive reliance on coercive methods and institutions and rather commission the EPA to introduce traditional rulers to UNESCO's Man and the Biosphere Programme [29] and/or the relevant aspects of the UN Sustainable Development Goals and facilitate the framing and adoption of GSCs which will commit galamsey endemic societies to uphold and practice high standards of ecological integrity. Over time, GSCs can be formalised as bylaws to be policed by local eco-civil society organisations constituted for that purpose under the auspices of traditional rulers and local authorities. In a theoretical sense, the GSCs will facilitate the emergence of solidarity-based eco-governance systems, which may be more sustainable than externally imposed regulations.

DECLARATIONS

Ethical consideration

The University of Ghana/University of York Galamsey Research was conducted in line with the Chatham House Rules with the prior and informed consent of its respondents.

Consent to publish

All authors agreed on the content of the final paper.

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Availability of data

The data for this work is available upon request from the author.

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A review of health hazards associated with exposure to galamsey-related pollutants

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Abstract

Galamsey, the unregulated artisanal small-scale gold mining in Ghana, is emerging as a significant global concern. Galamsey operations typically involve numerous unlicensed and untrained people at a multiplicity of sites who engage in the uncontrolled excavation of soil and/or water bodies using rudimentary tools. Aside from haphazard destruction of land and vegetation, galamsey operations often release hazardous substances such as mercury and cyanide, recognised as mining pollutants. This review examines the far-reaching implications of galamsey-related pollutants, drawing particular attention to the context of Ghana and focusing on the toxicological impacts of pollutants such as hydrocarbons, cyanide, mercury, lead, arsenic, soot, silt, and nitrate, often released during galamsey activities. These contaminants have been linked to various adverse health effects, including neurological disorders, respiratory diseases, cardiovascular issues, and congenital defects. Special attention is given to the mechanism of action of these pollutants, emphasising how they disrupt biological systems and lead to chronic health conditions and birth defects. Finally, the review proposes comprehensive recommendations for mitigating the health and environmental consequences of galamsey.

Keywords: Illegal mining sites, pollutants, socioeconomic, and galamsey

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INTRODUCTION

Galamsey, is an informal term used in Ghana for unregulated artesinal small-scale gold mining. This illicit activity involves untrained individuals excavating the earth and filtering soil and water with rudimentary tools to extract gold. This is usually done using inappropriate techniques, materials, and machines such as tractors, excavators, and grinding mills (known locally as Chamfi) to clear off the forest and vegetation, dig deep into the soil, and damage the soil structure. Other galamsey operators excavate riverbeds for alluvium. The obtained soil is washed to reveal nuggets of crude gold in a process that turns streams and rivers into muddy and high-turbidity

water bodies unfit for aquatic life. Galamsey-mined gold is processed in the open by untrained and ill-equipped labourers using toxic substances like mercury and cyanide, regarded as mining pollutants. The consequences of these actions include wanton destruction of vegetation, which contributes to the factors leading to changes in the climate. Galamsey activities also lead to land degradation, soil erosion, conflicts between humans and wildlife, water pollution, improper disposal of waste and various types of harm [1]. Ghana is one of the few sub-Saharan countries with abundant deposits of gold. During pre-colonial periods, Ghana was rich in gold, allowing ordinary individuals to gather gold dust and nuggets by excavating a few meters below the surface with simple implements such as pickaxes, shovels, and pans. In some instances, they could even stumble upon gold lying freely on the ground. During Ghana's pre-colonial days, gold was used as a

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currency in barter transactions for goods and services. The arrival of Western explorers, astounded by the region's abundant gold, led to naming the area as the "Gold Coast." They subsequently established a colonial presence, building forts and castles and developing industries focused on gold and the slave trade. However, the post-colonial period saw a shift from manual extraction to using chemicals in mining. These substances, even in small quantities, pose serious health risks, including hypertension, birth defects, brain disorders, kidney issues, and anaemia [2-7]. In Ghana, galamsey is prevalent in areas such as Tarkwa Nsuaem, Amenfi East, Prestea Huni-valley district, and Aboabo in the Western and Ashanti regions of Ghana, respectively [2]. According to the Ghana Statistical Service, about 2.4% of the labour force has been employed in the mining industry for the past two decades [8]. However, the substantial rise in the country's unemployment rate often leads many young people to engage galamsey, as a swift and effective method to support themselves financially [9,10].

Statistics from the Ghana Health Service (GHS) indicate a continual rise in birth mortality rates, stillbirths, and other birth-related complications in regions impacted by illegal mining [8]. In China [11], heavy metal ingestion by pregnant women, through direct or indirect exposure, led to issues such as lower newborn birth weight, reduced length at birth, and increased chances of preterm delivery. Additionally, there have been reports of other acute and chronic conditions, including gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, and cancer [11,12]. The yearly increase in birth defects linked to the consumption of water and food contaminated with heavy metals like arsenic, mercury, and lead parallels the surge in per-infant medical costs. This includes higher government spending on drugs and medical equipment for newborns. As a result, survivors of these birth-related issues often grow up unhealthy and less productive, becoming a liability rather than an asset to the country [13].

The adverse environmental impacts of galamsey, are widely recognised. However, this review paper aims to shed light on a crucial but often overlooked aspect: the health risks and birth defects resulting from exposure to galamsey-related pollutants. Evidence from existing literature has highlighted the alarming health problems prevalent in communities residing near these mining sites. A cross-sectional study by Cooper et al. established associations between maternal proximity to mountain-top removal (MTR) mining and increased birth defects [14]. This study highlighted the prevalence ratios of gastrointestinal defects in infants with varying degrees of MTR exposure. Another epidemiological study [15] found that heavy metals, especially the interaction of mercury with lead, had a significant correlation with the risk for Congenital Heart Defects (CHDs) resulting from prenatal exposure to these pollutants. In addition, findings from the Pediatric Society of Ghana revealed that exposure to the

heavy metals generated by illegal mining operations leads to a higher occurrence of congenital deformities, child fatalities, and cognitive impairments that have a detrimental impact on their academic performance [16]. These heavy metals upon entering the human body, tend to disrupt enzymatic processes, compromise the body's antioxidant defence mechanisms, and stimulate the generation of reactive oxygen species (ROS) [17].

This study also addresses the magnitude of health risks posed by galamsey-related pollutants to elucidate the potential health effects and birth defects associated with exposure to these pollutants. One of the repercussions of galamsey activities is respiratory complications [18]. Airborne respiratory disease, known as pneumoconiosis (black lung disease), is the major lung disease acquired by miners and operators of galamsey through inhalation of dust generated from the mining process [19]. According to Ayaaba et al., 47.5%, 14.3%, 9.69%, and 5.1% of gold miners (both regulated and unregulated) have been diagnosed with asthma, pneumonia, bronchitis, and emphysema, respectively, with coughing being the most prevalent symptom [20].

Galamsey-related pollutants

Several studies have confirmed elevated levels of various environmental pollutants in regions impacted by galamsey, as summarised in Table 1. This table provides a comparative analysis of the prevalence and distribution of these contaminants, highlighting the significant presence of toxic substances from illegal small-scale mining both in Ghana and globally. Such pollutants, particularly heavy metals such as lead, mercury, and arsenic, are often released during the gold separation process using chemicals like cyanide, sulfuric acid, and nitric acid. Acid mine drainage, erosion of waste residues, and primarily mining tailings are key sources of these pollutants. Tailings significantly contaminate water bodies and ecosystems with high concentrations of mercury, acid, arsenic, lead, and nickel. These pollutants pose a direct threat to the health of local residents in rural galamsey areas, who rely on rivers and streams as their primary water source. In addition to heavy metals, mining pollutants include hydrocarbons, cyanide, and particulate matter such as soot and silt, all contributing to potential health risks and birth defects associated with prolonged exposure [21,22].

Illegal mining activities result in the release of toxic petroleum hydrocarbons (fuel oils and grease) due to spills and leaks. Hydrocarbons can also be found in tailings, effluents, and waste materials generated by mining operations. The most common hydrocarbons from illegal mining activities include methane and volatile organic carbons (VOCs) such as benzene, toluene, ethylbenzene, and xylene. Nitrate, a prevalent pollutant in galamsey operations, primarily enters the environment through the use of blasting agents such as ammonium nitrate. During these galamsey activities, nitrate compounds are released and can swiftly infiltrate nearby water bodies. This

contamination poses significant risks to ecosystems and human health, as nitrates in water can lead to various environmental and health concerns, including water quality degradation and potential harm to aquatic life.

Case studies of galamsey activities in Ghana

Table 2 indicates the concentration of various pollutants found in different study areas in Ghana and other global regions, specifically focusing on the impact of galamsey activities. Based on the findings from Ghana: Studies conducted in River Tano [52], Tarkwa Nsuaem, Amenfi East, and Prestea Huni Valley [53] in Ghana revealed mercury concentrations in fish species and galamsey waste. Also, in the River Pra estuaries of Ghana, high concentrations of lead were reported in the water [58]. These significantly exceed the recommended health limits, indicating a serious health threat to both aquatic life and the local population. This could potentially lead to mercury and lead poisoning with associated neurological disorders and carcinogenicity [84]. In Kenyase in the Asante region of Ghana, the levels of cyanide found in yams were alarmingly high (43.47 mg/L), far exceeding the recommended limit of (10 mg/kg). This is particularly concerning as cyanide is highly toxic, leading to metabolic acidosis, cellular dysfunction, and organ failure at high exposures [85].

The Western region of Ghana, encompassing 22% of the country's drainage system, notably the Pra and Ankobra rivers [86,87], has faced the detrimental consequences of galamsey activities. The environmental impact is starkly evident through the presence of heavy metals like lead (Pb), arsenic (As), cadmium (Cd), and mercury (Hg) detected in fish samples collected from these rivers, as analysed by the Environmental Protection Agency (EPA) [88]. Levels of heavy metal contaminants (mg/L) detected in River Pra in the Ashante region of Ghana ranged from 0.12 - 0.26 for Cd, 8.65 - 8.48 for Pb, and 0.50 - 0.08 for Hg [119]. Consuming fish contaminated with these heavy metals has been linked to damage to the nervous system and the occurrence of birth-related disorders [58,89]. Additionally, a study conducted in areas such as Sanso, Anyinam, Anyimadokrom, Abombe, and Tutuka within the Obuasi municipality has reported a significant increase in cases of skin diseases, colds, catarrh, and respiratory illnesses, accounting for 27% [90,91].

These findings underscore the dire environmental and public health consequences of galamsey activities in the region. Among the reported sites, Anyimadokrom emerges as the most significantly affected by galamsey-related pollutants, owing to its close proximity to galamsey operations [92]. Instances of galamsey-related health issues, such as skin diseases, are particularly prevalent in Anyimadokrom, with 26.6% of respondents reporting these problems, as opposed to other areas like Sanso, where 24.3% of responses were recorded [91]. This data indicates the heightened impact of galamsey activities on the health of the local population in Anyimadokrom compared to neighbouring areas.

Recommendations and future perspectives

This study unveils a pressing need for proactive measures to address the multifaceted challenges posed by galamsey activities in affected communities. The following recommendations and future perspectives are proposed to chart a path toward sustainable solutions.

- Mitigating Political Influence on Galamsey:** The persistent issue of political influence on galamsey must be tackled at its root. Authorities should institute stringent regulations and enforce them without compromise, irrespective of political interests. Government agencies, in collaboration with relevant stakeholders, should implement policies to prevent illegal mining operations and penalise those who facilitate or engage in these activities.
- Advanced Research on Bioavailability:** While extensive quantitative and analytical research has been conducted on galamsey-related pollutants, a deeper understanding of their bioavailability is essential. Comprehensive bioavailability assessments should be carried out to precisely determine the levels of these pollutants in the affected population. This information is critical for designing targeted intervention strategies and assessing the health risks accurately.
- Enhancing Healthcare Infrastructure:** Many health centres in galamsey-affected areas and Ghana as a whole lack the necessary technologies to detect and monitor chemical contaminants in affected individuals. To bridge this gap, toxicological divisions should be established within healthcare facilities. These divisions would be equipped with state-of-the-art equipment for diagnosing and monitoring the health effects of galamsey-related pollutants, ensuring timely and accurate healthcare provision.
- Investment in toxicological assays and the availability of readily accessible assays for detecting galamsey-related pollutants is paramount.** Investment in the development and widespread deployment of assays for quantifying pollutants, including but not limited to cyanide, is essential. Such assays should be made accessible to healthcare professionals, allowing for rapid, on-site testing of affected individuals.
- Community Education and Awareness:** Education and awareness campaigns should be intensified to inform individuals about the dire consequences of galamsey. These campaigns should encompass not only the health risks but also the environmental and socioeconomic impacts of illegal mining. Community engagement and awareness programs can deter participation in galamsey and encourage responsible practices.
- Robust Water Treatment Systems:** Galamsey-affected communities should have access to robust water treatment systems that can help remove contaminants from drinking water sources. Investing in these systems is vital for ensuring the availability of safe, clean water, which is a fundamental requirement for public health.

Table 1 Overview of Gamamsey-Related Pollutants, Adverse Health Effects, and Mechanisms of Action

Pollutant	Adverse Health Effects	Mechanism of Action
Hydrocarbons (PAHs, VOCs, methane, fuel oil and grease)	Central nervous system damage and Increased risk of leukemia, impairment of fetal growth [23,24]. Congenital health defects on offsprings (conotruncal heart defect) [25]	Hydrocarbons metabolize into toxic intermediates that damage (Deoxyribonucleic Acid) DNA and proteins, increase mutation risk, and induce oxidative stress, generating reactive oxygen species that cause cellular damage.
Cyanide	Metabolic acidosis, Cellular disfunction, organ failure and induce central nervous system dysfunction [26]	Cyanide's inhibits cytochrome c oxidase, a crucial enzyme in the electron transport chain of mitochondria, responsible for aerobic respiration. $Cyanide (CN^-) + Cytochrome\ c\ oxidase \rightarrow CyanideCytochrome\ c\ oxidase\ complex$ [27-29]
Mercury	Organ dysfunction (brain, renal, endocrine glands), stillbirths and neurological disorders (tremors, impaired cognition, muscle weakness) and causes neural tube defects [30]	Galamsey activities release organic mercury, bonding with proteins, altering structures, causing organ dysfunction. Methyl mercuric-cysteiny complex crosses placenta, leading to birth defects. $[MeHg]^+ + RSH \rightarrow MeHg-SR + H^+$ [31-33]. Where= RHS = Alkyl thiol or alkanethiol, $MeHg-SR$ = methyl mercuric-cysteiny complex
Lead	Reduced erythrocyte resilience, anemia, Impaired heme synthesis, disrupted hemoglobin production, shortened red blood cell lifespan, [34]. Damages the central nervous system, cognitive impairments, and an increased risk of hypertension and cardiovascular disease in adults [35].	When introduced as lead phosphate, lead undergoes precipitation in the blood, creating an acidic environment that weakens erythrocytes (red blood cells) and reduces their oxygen-carrying capacity. $Pb_3(PO_4)_{2(s)} + H_2O_l \rightarrow H_3PO_{4(aq)} + 3Pb^{2+}_{(aq)}$ [34].
Arsenic	Skin lesions, respiratory tract infections and increased risk of cancer	Once ingested, inorganic arsenic undergoes methylation to form organic arsenic compounds, but this does not mitigate its health risks. Both inorganic arsenic and its organic metabolites disrupt cellular processes, leading to severe health issues [36].
Soot	Respiratory problems (asthma, bronchitis), coronary heart diseases and Premature birth, low birth weight [37,38].	Combustion of fuels emits soot particles and droplets into the air which disperse into the surrounding environment. leading to significant health risks due to Inhalation of soot-laden air. [39].
Silt	Reduced water quality resulting in water borne diseases [40].	Galamsey activities disrupt water bodies through soil erosion and alluvial mining, leading to substantial accumulation of suspended sediments in the water, known as siltation. [41].
Iron	Neurotoxicity	A chemical interaction between iron and hydrogen peroxide (Fenton Reaction), produces hydroxyl radicals ($OH^\bullet$), which are extremely reactive and harmful to living cells. These $OH^\bullet$ radicals interact with various biomolecules in the bloodstream, compromising enzymatic activities and causing damage to proteins, lipids, nucleic acids, and DNA strands. $Fe + H_2O_2 \rightarrow OH^\bullet + Fe^{2+}$ [42,43]
Vanadium (V)	Nausea, vomiting, abdominal pain and tongue discolouration	When in contact with blood plasma containing Nicotinamide adenine dinucleotide phosphate (NADPH) and ascorbic acid, V transforms into a reduced form. This reduced V then reacts with oxygen in the bloodstream to generate an oxygen radical. This radical further reacts with V, allowing its transportation to various parts of the body [44].
Carbon monoxide (CO).	Otitis media, asthma, autism spectrum disorder (ASD), small for gestational age. Reduced oxygen delivery impairs fetal growth and development	CO binds with haemoglobin to form carboxyhemoglobin (COHb) in the blood, reducing oxygen delivery to the foetus. This contributes to neurological disorders by affecting the delivery of oxygen to the brain during critical periods of foetal development and exacerbate respiratory conditions by impairing oxygen transport and causing inflammation in the respiratory system [45].
Nitrate (from blasting agent, ammonium nitrate)	Prenatal exposure to nitrates mostly through drinking water causes childhood cancer, preterm delivery and lower birth weight, Infant mortality, congenital cataract, neural tube defects including Spina Bifida and affects the heart of offsprings [46,47].	Nitrates, undergo conversion in the body to nitrites, which can then further react to form N-nitroso compounds. These compounds are of particular concern due to their potential carcinogenic and teratogenic effects. In the case of pregnant women, these N-nitroso compounds can cross the placenta, potentially interfering with foetal development and leading to birth defects, particularly affecting the central nervous system and possibly other organ systems [48].
SO ₂ (Sulfur Dioxide)	Congenital limb defects and neural tube defects in offsprings [49, 50], respiratory problems, aggravation of existing cardiovascular diseases, irritation of the eyes, nose, and throat [51].	SO ₂ generated from the combustion of oil in gamamsey machines dissolve in water vapour in the air to form sulfurous acid (H_2SO_3), which is a respiratory irritant. When inhaled, it reacts with the water lining of the respiratory tract, forming acidic compounds that irritate the respiratory system. This leads to bronchoconstriction and increased asthma symptoms [51]

Table 2. Reported Levels of Gamamsey-Related Pollutants in Different Study Areas

Pollutant	Study Area	Sample Type	Concentration	Recommended Limit
Mercury	River Tano, Ghana. [52]	M. rume fish species	(1.01 ± 0.03) mg/Kg	≤ 0.5mg/Kg [55]
	Tarkwa Nsuaem, Amenfi East and Prestea Huni Valley, Ghana. [53]	L.niloticus fish species	(1.1 ± 0.14) mg/Kg	
		gamamsey waste	(0.0060 ± 0.0004) mg/Kg	≤ 4mg/Kg [56]
		Blood of birds	(0.23 ± 1.09) µg/L	
Lead	Cispatá Bay, Colombia. [54]			
	Lake Badovci, Kosovo. [57]	Water	0.01 mg/kg	(0.01-0.015) mg/L
	River Pra estuaries, Ghana. [58]	Water	(8.65 ± 8.48) µg/L	[60]
Arsenic	Dagua River estuary, Colombia. [59]	Sediments and Tissues of A. tuberculosa	(0.87 ± 0.68) mg/Kg	
	Central Yinchuan basin, China. [61]	Groundwater	(0.7-26) µg/L	≤ 10 µg/L [64]
	Mojana region, Colombia. [62]	Blood of children and Adolescents	1.96 ± 2.73) µg/L	
	Caracoto, Peru. [63]	Groundwater	(31.9-113.1) µg/L	
Cadmium	Fena River, Ghana. [65]	Water	(0.14 ± 0.19) mg/L	≤ 0.005ppm [68]
	Pawara, Eastern Cameroon. [66]	Soil	(12.2-25.0) mg/Kg	≤ 0.6mg/Kg [69]
	La Oroya Antigua, Ecuador. [67]	Soil	4,820ppm	
Hydrocarbons	Suixi County, China. [70]	Soil	(218-1548) ng/g	≤ 100mg/Kg [73]
	Henan Province, China. [71]	Groundwater	(146.9-1220.6) ng/L	≤ 300g/L [74]
	Harare, Zimbabwe. [72]	Soil	21,415 mg/Kg	≤ 100mg/Kg
Soot (Particulate matter)	Bochnia, Poland. [75]	Air	(21-79) µg/m ³	≤ 35mg/m ³
	Kiruna, [75]	Air	94 µg EC m ⁻³ and	
	Norrbottn County, Lapland, Sweden. [76]	Air	1200 µg NO ₂ m ⁻³	
	Kemi-Tornio region, Finland. [77]		(22-1100) µg m ⁻³	
Silt	Central Gold Belt, Malaysia[78]	Soil	78.23% sludge, 68.06%	
	Tapajós river basin, Brazil. [79]	Water	waste dump, 63.98%	
	South-western Rivers system, Ghana. [80]	water	stockpile HG, 60.65% stockpile SLG and 53.21% sediment ~5.0 mgL ⁻¹ 382 mg/L	
Cyanide	Kenyase, Ghana. [81]	Yam	43.47 mg/L	≤ 10mg/Kg
	Jilin, China. [82]	Water	2.5 mg/Kg	
	Kelantan, Malaysia. [83]	urine	0.56 mg/dL	≤ 0.2g/L

- g. Sustainable Mining Practices: Promoting sustainable mining practices and encouraging small-scale miners to transition to legal and responsible mining activities should be a long-term objective. Government incentives and support can facilitate this transition, creating alternative livelihoods for those currently engaged in gamamsey.
- h. To safeguard pregnant women and mitigate the risk of birth defects, it is essential to enhance environmental monitoring and control in areas prone to pollution from sulfur dioxide, cyanide, carbon monoxide, and hydrocarbons. Healthcare providers should offer regular screenings and advice on avoiding exposure.

Conclusion

This review has extensively explored general pollutants generated and related to illegal gold mining operations and delivered parallels to the specific pollutants generated from gamamsey operations in Ghana. The findings presented highlight the dire health implications and congenital defects associated with exposure to pollutants. Notably, mercury,

lead, arsenic, and other heavy metals have been linked to severe neurological and developmental disorders, respiratory diseases, and cardiovascular problems. Pregnant women and their unborn children are especially vulnerable, with exposure leading to birth defects such as neural tube defects, congenital heart defects, and low birth weights. Also, sulfur dioxide, cyanide, carbon monoxide, and hydrocarbons have all been associated with significant birth defects and developmental problems. Exposure to these pollutants can lead to congenital heart defects, neurological issues, and impaired foetal growth, highlighting the critical need for protective measures for pregnant women.

The health risks and birth defects associated with exposure to gamamsey-related pollutants are a public health emergency that requires immediate attention. This review serves as a call to action for policymakers, healthcare providers, and the community to work together to eradicate the scourge of illegal mining and its devastating health consequences. A united and comprehensive approach can protect current and future generations from the harmful effects of gamamsey.

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None

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Review

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Vulnerability to infectious diseases and risk reduction measures among galamsey gold mining communities in Ghana: A narrative review

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Abstract

Galamsey is an artisanal and small-scale gold mining practice that is illegal in Ghana. Miners, their families and communities are at an increased risk of infectious diseases due to the short - and long-term health and environmental effects of galamsey activities. Infectious diseases are caused by pathogens such as bacteria and viruses and can spread from person to person directly or indirectly. Some of the mechanisms of the increased risk of infectious diseases associated with Galamsey include poor sanitation in mining communities, leading to the proliferation of gastrointestinal and diarrhoeal diseases such as cholera and typhoid, and alterations in the environment and natural ecosystems that enhance the transmission of emerging/re-emerging diseases and other priority diseases such as malaria, dengue fever, yellow fever, rabies etc. The legislative instrument that guides mining activities in Ghana, the Minerals and Mining Act 2006 (Act 703), as well as other minerals and mining laws/policies, provide a framework for mining which protects the environment and human health. Enforcement of these by regulators and law enforcement actors is key to reducing these infectious disease vulnerabilities in mining communities. Health promotion and sensitisation of miners and members of the mining communities will help prevent and mitigate the health risks posed by galamsey mining activities.

Keywords: Artisanal and small-scale gold mining, infectious diseases, zoonotic spillover, galamsey

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INTRODUCTION

Artisanal and small-scale gold mining (ASGM) is mining that takes place on a relatively smaller concession of land (up to 0.1 km²) [1,2]. The exact definition of ASGM is varied but has some defining characteristics. It is informal, usually illegal and has limited capital investment in the trade [3]. The work processes employed are typically rudimentary, inefficient and labour-intensive, resulting in low productivity in terms of commercialisation. The illegal form of ASGM is referred to as galamsey in Ghana. In recent times, however, more sophisticated equipment has been used in ASGM. Persons engaged in the trade are usually poor people with low levels

of education. Worldwide, between 15 - 40 million people are employed by the ASGM sector, which accounts for 20 - 25% of global gold production [4]. In Ghana, an estimated 1 million persons are employed directly by the sector [1]. It contributed to 43% (2.1 million oz) of total gold production in 2018, 36% in 2019, and 30% in 2020 in Ghana [5].

In Ghana, about 70% to 80% of all small-scale mining is informal [1]. The license for small-scale gold mining in Ghana is given to Ghanaians, who can partner with other nationals to provide mining resources. General health risks of miners include accidents, heat strokes, heat exhaustion, infectious disease hazards, dust, toxic chemicals, violence, and social vices [6,7]. ASGM is the world's single most important source of mercury exposure in the environment, putting the miners and their communities at high risk of mercury exposure and its attendant effects. However, employment for the poor and ready market for the precious

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mineral sustains the trade [8]. Miners, ex-miners, their families and persons living in mining communities have an increased vulnerability to infectious diseases such as malaria, typhoid fever, and cholera. Most of these are directly related to the processes involved in gold exploitation as well as other contextual factors. Literature discussing the comprehensive multifactorial vulnerability to infectious diseases due to ASGM is limited. This paper—a narrative review, explores both the direct and indirect short and long-term factors that increase the risk of infectious diseases associated with ASGM.

The mining process in ASGM

The ASGM involves excavation of the gold ore, which can be obtained from the earth's surface (surface mining), deep within the earth's crust or from river beds (alluvial mining) [9]. Processing involves several stages. First is the crushing and milling of the ore, followed by the concentration of the gold. Concentration of the gold is done using gravity and sedimentation during the panning/washing of the milled ore. Mercury is then added to the concentrated gold to form a mercury amalgam that is burnt or roasted to separate the mercury from the gold. The gold is refined by further heating.

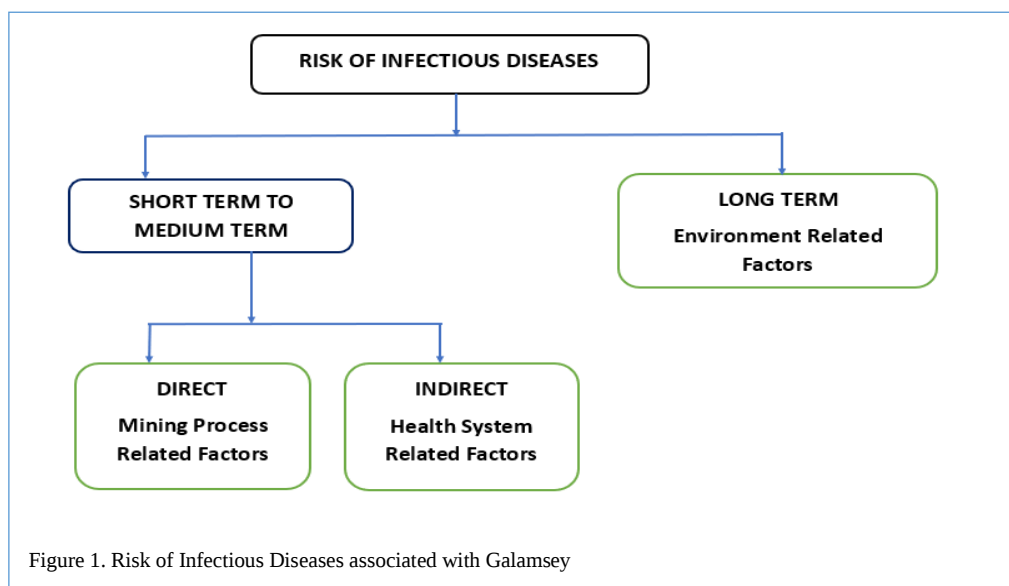
Vulnerability to infectious diseases in galamsey

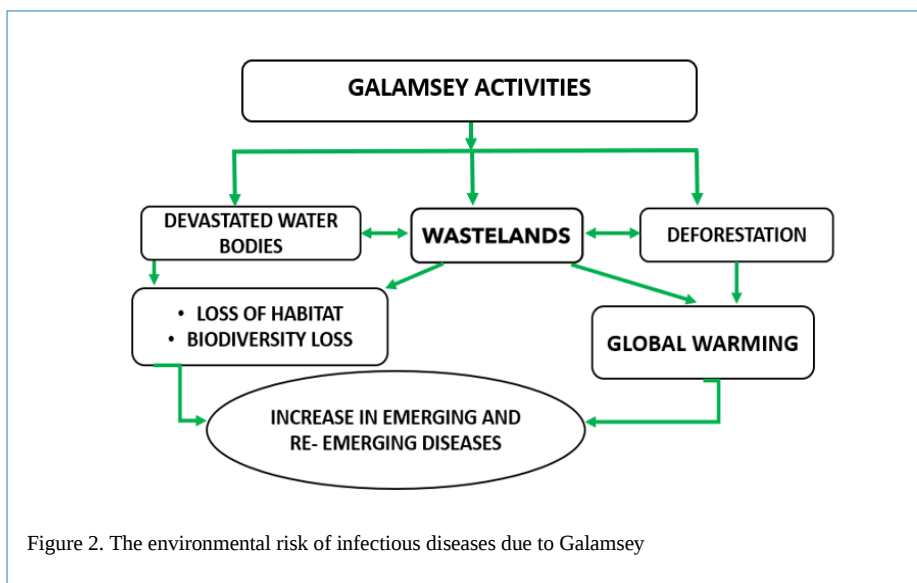
Infectious diseases are caused by organisms that include bacteria, viruses, fungi and parasites. These are biological agents that tend to spread from person to person directly, through the air, through contaminated inanimate objects, food/water, or biological vectors such as mosquitoes and rats. Infectious diseases constituted the most frequent group of diseases in the Illness category among prehospital emergencies in illegal gold mining sites in Guiana [10]. The risk of infectious diseases can be divided into short-term and long-term factors, as shown in Figure 1.

Short-term direct factors (mining process-related factors)

Blasting, drilling, crushing, milling, sieving of the ore, etc., release dust particles into the atmosphere, which can cause silicosis when inhaled over time by miners, their families and communities [11]. Silicosis increases the risk of tuberculosis by 30 - 40 times. The triad of HIV, TB and Silicosis, a public health problem when present, carries a relatively high mortality rate among patients [12,13]. In 2014, the World Bank estimated that South African miners had the highest occurrence of TB cases than any other profession globally (2500 – 3000 cases per 100,000 people) [14]. The release of dust particles into the atmosphere also carries the risk of increased incidence of acute respiratory tract infection, especially among children [8]. Children living in Obuasi, a mining town in Ghana, were found to have significantly more cases of acute upper respiratory tract infections than children in Asankragwa, a non-mining town, in a comparative study [15]. In Suriname and DR Congo, similar findings were reported [16]. Living in gold mining towns was found to be the only significant risk factor for developing pneumonia in a retrospective cohort of children in Fiji [17].

Ponding of rivers, especially from alluvial Galamsey mining activities and stagnation of water found in and around mining sites, enhances the breeding of mosquitoes. This carries an increased risk of transmission of mosquito-borne diseases such as malaria, dengue, yellow fever and elephantiasis [9,18,19]. A cross-sectional study carried out in Ghana showed that malaria prevalence in artisanal gold mining towns among children under five years is higher than that found in non-artisanal gold mining communities [20]. A malaria surveillance system in Guiana, among armed forces, linked high malaria incidence to illegal small-scale gold mining [18]. Again, the routine wading through these stagnated water and moist soil increases the risk of





worm infestations transmitted through the skin, as well as other skin infections. Poor sanitation has frequently been found in and around the mining towns. Miners are discouraged from erecting water sanitation and hygiene (WASH) facilities at the mining sites because these are temporary sites in remote areas [9]. Also, chemical and heavy metal pollution of drinking water sources leads to the shutdown of water treatment plants, making community members turn to untreated water sources for their daily water needs. Open defecation, inadequate WASH facilities and polluted/ untreated drinking water sources increase the risk of diarrhoeal diseases, notably cholera, shigellosis, giardiasis, *E. coli*, Hepatitis A & E, Cryptosporidiosis, guinea worm, etc. [8]. In-migration into mining towns leads to overcrowding, which carries an increased risk of respiratory tract infections and scabies. Associated increased promiscuity in mining towns leads to increased prevalence of sexually transmitted infections such as gonorrhoea, syphilis, chlamydia and HIV infection [9].

Short-term indirect factors (health system-related factors)

Many mining communities are located in remote rural geographical locations. Weaker health systems and lower sophistication in the skilled health workforce, facilities and diagnostic capabilities, medications and technologies are characteristic of these remote/hard-to-reach mining towns [9]. Some conditions pose a diagnostic challenge in detection, and therefore, timely management may be missed. An example is typhoid fever. Subsistence miners who are poor have low purchasing power, which constitutes a financial barrier to accessing healthcare [8]. In-migrants also put pressure on these limited health resources, reducing their effectiveness.

Long-term environment-related factors.

Stable ecosystems and biodiversity ensure the resilience of our ecological framework [21]. Galamsey activities

degrade the environment by clearing forests, destroying arable land and polluting water bodies, leaving them devastated and deforested as wastelands. Destruction of the environment leads to the loss of the natural habitat of organisms and the loss of biodiversity in the ecosystem [12,22]. As natural habitats are lost, relative populations of definitive hosts reduce. This is due to altered intra- and inter-habitat species distribution, altered movement, and altered interactions with other species and the environment. There may also be an altered interaction between the reservoir of disease and the disease-causing agents, leading to a spillover of zoonotic diseases that were originally not known to be transmitted from man to man [22–24]. Also, the destruction of the environment driving global warming and climate change leads to an increase in the respiration and metabolism of species, as well as the increase in their reproductive rate [25,26]. This also leads to an increase in the relative populations of disease-causing vectors [21]. Encroaching into forests for illegal mining activities also leads to an increased proximity of man to the wild. The resultant effect of these is that disease-causing vectors are more efficient at transmitting disease, and the occurrence of emerging and re-emerging diseases such as Dengue fever, Lassa fever, Marburg and Ebola virus diseases, Yellow fever, etc., increases.

Infectious risk mitigation measures

For these infectious disease risks to be mitigated, it is important that there is enforcement of regulations and safety standards contained in the Minerals and Mining Act 2006 (Act 703) and the Mining Policy 2014 by officers of the Minerals Commission, Ministry of Lands and Natural Resources, Environmental Protection Agency (EPA), Forestry Commission and law enforcement agencies [27]. Parallel to regulations enforcement, Public Health takes a more persuasive approach to social and behavioural change in order to protect life [12]. Studies done in Ghana show that miners have low knowledge levels of these hazards and

the risks the trade puts on them and their communities. Health education and health promotion measures are key to sensitising them to these occupational and environmental health risks [9]. They should be urged to adopt environmentally safer methods of mining. Some occupational health risk reduction measures include dust control measures, modification of work process, e.g., using wet methods instead of dry, dusty methods, modified milling, use of face masks, boots and other personal protective equipment, practising safer sex, etc. [27,28]. Health education on practising good hygiene, which includes avoiding open defecation, washing hands before eating and washing hands after using the toilet, is key to reducing the risk of diarrhoeal diseases. Environmental health officers should provide technical guidance for the construction of environmentally safe latrines for use in these mining communities.

It is imperative that health-related aspects of research into 'galamsey' are conducted to generate evidence aimed at health interventions. Primary and secondary data on humans, animals and the environment, as well as specifically the perceptions of the miners and the mining communities, need to be sought in the evidence generation [29] to inform public health education in ASGM communities. Healthcare workers, especially those who work within galamsey communities, should be trained to detect and appropriately manage and refer to the range of infectious disease risks galamsey miners and their communities face. This will strengthen the sensitivity of the local health surveillance systems to identify conditions such as diarrhoeal diseases, typhoid fever, infestations and the triad of HIV, TB and silicosis, to mention a few. Strengthening the surveillance system in these communities is important for driving primary and secondary disease prevention.

Conclusion

Informal small-scale gold mining has been in existence for centuries and contributes to the GDP of countries where it is practised. The trade, however, comes with increased vulnerability of the mining communities and society at large to infectious diseases. These include short-, medium- and long-term infectious disease risks that need to be mitigated to protect lives and the ecosystem. Healthcare workers who work within these rural mining communities are better placed to educate the communities on an ongoing basis on the health risks and provide solutions. For this purpose, they should receive adequate ongoing training from healthcare managers. Academics working together with industry, mining communities, government regulatory and health machinery, and partners (financial and technical) should develop multisectoral evidence-based solutions to mitigate the infectious disease risk posed by galamsey.

DECLARATIONS

Ethical considerations

Not Applicable

Consent to publish

All authors agreed on the content of the final paper.

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Competing Interest

None

Author contributions

AAA and BNLCCT conceptualised the study. All authors researched and reviewed relevant literature. All authors participated in writing the paper and reviewed/approved the final version submitted.

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Availability of data

The data for this work is available upon request from the corresponding author.

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Statement on Illegal Mining

The Ghana Academy of Arts and Sciences**Special Edition on Galamsey***Received April 2024; Revised May 2024; Accepted June 2024***Keywords:** Illegal mining, environmental degradation, galamsey, surface mining, land reclamation

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Ghana is on the brink of an environmental, health and social disaster as a result of illegal mining. We are rapidly approaching the precipice despite the efforts by successive governments to address this menace. The latest 'Fight Against Galamsey' has failed in spite of the legal-institutional framework that was put in place. For instance, although the Minerals and Mining (Amendment) Act, 2019 (Act 995) was passed to specifically redefine the offence of illegal mining (including illegal small-scale mining such as galamsey) and to provide punishment for it, the government has proved unwilling, unable and/or reluctant to enforce the law. The two versions of 'Operation Halt,' the military operation to root out illegal mining, have also petered out.

The thrust of the high-profile efforts to stop illegal mining revolved around arresting some of the operators and seizing or burning their equipment, which have not only proved ineffective but has also posed environmental, health and social challenges. Illegal mining has a very large footprint in the form of campsites, heavy-duty earth-moving equipment, processing plants, and large communities of migrant labourers that must be fed and housed. This begs three questions, namely (i) How can heavy equipment reach illegal mining sites without detection? (ii) How can large volumes of fuel and materials reach illegal mining sites without detection? and (iii) How can the financiers providing the large amounts of money necessary for illegal mining conduct their financing and investment activities without detection? Illegal mining continues to thrive because the kingpins who supply and fund the operations have not been vigorously pursued and prosecuted. More detective work to identify and hold the financiers and suppliers liable for illegal mining should be the centrepiece of a rejuvenated 'Fight Against Galamsey'. Civil society has made countless demands on successive governments,

ranging from simply enforcing the law to possibly confiscating lands on which the activity occurs. Some traditional authorities have taken it upon themselves to prevent surface mining activities within their jurisdictions, challenging or invalidating licenses and permits issued by government bodies. Some traditional authorities have destooled or threatened to destool chiefs who are complicit in or condone galamsey activities in their jurisdictions. Meanwhile, there is a continued upsurge of galamsey in our rural communities, stimulating truancy among school-going males and loss of lives and injuries as a result of the collapse of galamsey pits, while the environment is being degraded with impunity. The scale and extent of surface mining, with or without official licenses, buttressed with the use of arms and offensive weapons to protect workers, property and equipment are a major threat to national security, peace, and stability.

Against this backdrop, the Ghana Academy of Arts and Sciences (GAAS) can no longer sit in silence. The Academy is therefore appealing as a matter of urgency to the Executive, Parliament, the Judiciary and non-state actors such as the National House of Chiefs, the Trades Union Congress, civil society, professional associations, media, faith-based organisations and students to take collective action to stop the existential threat posed by illegal mining.

A Brief Review of the Legal Framework

Artisanal mining had been part of the political and economic history of Ghana for centuries before the colonial administration introduced legislation that demanded levels of government licensing for mining. This legislation made it almost impossible for the local population to undertake legal mining, which was effectively limited to the state or big-money foreign interests. However, with the

implementation of the Economic Recovery Programme (ERP) by the Provisional National Defence Council (PNDC) in 1983, significant changes were introduced in the mining sector. Key among them is the promulgation of the Minerals and Mining Law (PNDC Law 153) in 1986, which established the Minerals Commission to regulate the sector and further liberalise the mining climate, extending significant new benefits to investors in the area. It also gave grudging legal recognition to artisanal mining, defined as mining 'by methods not involving substantial expenditure or the use of specialised technology.' This made it possible for the local population to engage in legal mining. Perhaps to give more recognition to artisanal mining, the Small-Scale Gold Mining Law (PNDC Law 218) of 1989 was enacted to regularise the operations of small-scale gold miners and to protect the environment.

In 2006, all mining laws in Ghana were consolidated with the passage of the Minerals and Mining Act (Act 703), which is a more forward-looking law and recognises both the potential wealth and potential danger of artisanal mining. The Act has a whole chapter regulating artisanal mining with respect to the subsequent amendments (Act 900 of 2015 and Act 995 of 2019), which have created specific offences and penalties. It requires the designation of areas for artisanal mining; stipulates the terms and conditions for obtaining a license and when it may be revoked; authorises the establishment of District Offices of the Minerals Commission to register, monitor and provide advice to artisanal miners; and orders the setting up of small-scale mining committees in every district to monitor and develop operations in designated areas. In short, the Act provides for the use of effective methods, good mining practices, health and safety rules and protection of the environment. Regrettably, however, successive governments have simply been incapable of translating these fine rules into action. There has been an inexplicable unpreparedness, unwillingness and/or inability of the governments to apply and enforce the law, set up the required structures and resource them to work well. These, in part, account for the lack of proper industry regulation.

A major drawback to the legal framework is the passage of the Environmental Protection (Mining in Forest Reserves) Regulations, 2022 (L.I. 2462), which allows unfettered access to the forest reserves of the country through the granting of Forest Entry Permits for mining by the Forestry Commission. L.I. 2462 was intended to bridge the gaps in environmental regulations in the mining sector and replace the inadequate and unclear guidelines of the Environmental Protection Agency (EPA) that had governed mining in forest reserves since 2000. We consider this legislation to be inimical to good mining practices and environmental sustainability because it has the potential to attract more unregulated mining investments into the forest reserves. This situation is compounded by doubts about the capacity of the Forestry Commission to implement and enforce mining regulations.

Concerns of the Ghana Academy of Arts and Sciences

GAAS is deeply concerned about the current crisis generated by the wanton destruction of our environment by surface mining. The Academy is concerned that the environment that provides all the natural resources for our well-being as a people is being destroyed and that citizens have become powerless, watching and not able to do anything about it.

GAAS' concerns are because:

1. The topsoils in vegetated areas and the volume and quality of water in riverbeds and other water bodies contain all the necessary elements of biotic nature (living resources including plants, animals, mushrooms, and microbes) and abiotic nature (non-living resources such as soils, wind, currents, temperature, essential chemicals, e.g., carbon, oxygen, rocks, substrates, and sediments).
2. These elements create a sustainable soil and water structure for production.
3. Production is maintained because of the delicate and intricate balance between these elements.
4. It is through sustained production that energy (captured and accumulated in food substances and other materials) and matter (the assimilated substances that create growth and which are noted as productivity) are distributed in a structured manner to create an ecosystem.
5. Terrestrial and aquatic productivity is maintained in natural environments, on agricultural and plantation fields, and in fishery locations in rivers, lakes, ponds, lagoons, estuaries and the shallow and deep waters of the ocean;
6. The disruption in this ecosystem arrangement reduces productivity and compromises the environment.
7. The loss of productivity reduces and/or completely depletes the goods and services that the ecosystem can provide for socio-economic development.
8. Water bodies are destroyed, water is polluted, and potable water is unavailable or difficult to find. This generation is, therefore, creating the conditions to deprive our children, grandchildren and future generations of water, a basic necessity for survival.
9. The health of communities in areas with surface mining is compromised, and hitherto uncommon diseases and medical conditions associated with heavy metal poisoning, including cancers, birth defects, kidney dysfunction and nervous system disorders, are aggressively manifesting themselves in our communities.
10. The phenomena described in 6, 7, 8, and 9 are occurring in almost all parts of Ghana at alarming rates as a result of surface mining.

GAAS demands that this situation be addressed immediately to prevent a future catastrophe of human suffering from this environmental damage to our landscapes and waterscapes.

The Way Forward

Crisis times and situations of this kind demand very drastic policy actions, especially when Ghana is committed to sustainable development as declared in signed multilateral environmental agreements such as the Sustainable Development Goals (Agenda 2030), the Africa We Want (Agenda 2063), the Paris Agreement on Climate Change, and the Montreal-Kunming Global Biodiversity Framework.

We are aware that illegal mining and the destruction of our forests are driven by economic as well as political factors. There is a lack of jobs, and therefore attempts to stop illegal mining will face serious resistance since livelihoods will be threatened. However, there is a need for effective regulation and a strong political will to ensure that livelihoods are not unduly threatened while the wanton destruction of the environment is curtailed. Truth be told, funding for political activities has benefited from illegal mining, and politicians have flouted regulations on mining with impunity. We demand that going forward, all political party manifestos explicitly state how the parties intend to address this menace. We will hold them responsible and accountable during their term of office. We demand that traditional authorities educate and mobilise their people to combat illegal mining in their jurisdictions, and we call upon civil society to always hold miners environmentally accountable. Accordingly, GAAS demands that the government implement the following policy actions:

1. Declare a moratorium on all kinds of surface mining activities around river bodies;
2. Revoke all reconnaissance and prospecting licenses, mining leases and small-scale mining licenses in forest reserves and other fragile ecosystems such as Key Biodiversity Areas;
3. Revoke the Environmental Protection (Mining in Forest Reserves) Regulations, 2022 (L.I. 2462); and
4. Establish a plan for land reclamation in all areas destroyed by illegal mining and other forms of surface mining.

A moratorium for ten years or more around river bodies would allow the fragile ecosystems to recover from the destruction. This may not guarantee full recovery in the areas affected, but it would at least help to rebuild the resilience of those components of our ecosystems (including water bodies and forest reserves) to support the ongoing efforts at reducing biodiversity loss, contribute to adaptation to and mitigation of climate change, avoid land and water degradation, and support the global goal of the decade on ecosystem restoration from 2021 to 2030. Surface mining, especially in forest reserves, defeats the main purpose of such reserves because it undermines the fabric of sustainability of the ecosystem in areas where the livelihoods of our local people are guaranteed. When this happens, the subsistence rural economy of the people disintegrates, and they become deprived, leading to extreme poverty. There is, therefore, the need to conduct an immediate forensic environmental audit of all surface

prospecting licenses, mining leases and small-scale mining licenses in forest reserves. Any license or lease holder found to have breached the environmental regulations should immediately lose the license or lease. Those in good standing should be offered new concessions outside of the forest reserves and given the necessary support to enable them to reestablish their operations at the new locations. During the transitional period, they should be subjected to more rigorous environmental monitoring and assessment to ensure that the harm is either eliminated or drastically reduced. Certainly, there should be no renewals if their leases and licenses in the forest reserves expire before they are completely relocated.

While the Academy would have demanded immediate revocation of licenses and leases in the forest reserves, we are fully aware of the legal implications. We know that investors aggrieved by the revocation of leases, licenses and permits may resort to litigation. That is why the Academy is proposing an audit-based revocation, stricter implementation of the laws, allocation of new concessions to operators in good standing and non-renewal of the licenses and leases when they expire. The Academy finds the enactment of L.I. 2462 not simply a troubling contradiction but a completely tone-deaf response to the problem of illegal mining. It beggars belief that when we have proven to be so incapable of regulating illegal mining in open places, the Minister of Environment, Science, Technology and Innovation and the Board of the Environmental Protection Agency (without the necessary stakeholder consultation) would send subsidiary legislation to Parliament in 2022 to license mining in our already-fragile forest reserves. It is even more shocking that Parliament dropped the ball by allowing this L.I. to gestate without annulling it under its Article 11(7) powers enshrined in the 1992 Constitution to protect Ghanaians.

The Academy demands the immediate revocation of L.I. 2462. It was enacted in extremely bad faith. What it seeks to do is not in the best interest of the people of Ghana. The conservation of forests is, in fact, meant for posterity, generations of Ghanaians yet unborn, and it can foster future scientific research to provide solutions for the three global environmental crises, namely climate change, pollution and biodiversity loss. Literally, the entry into forests and other reserved landscapes goes against all the programmes of work of the multilateral environmental agreements to prevent land and water degradation, advance adaptation and mitigate climate change, and reduce and/or stop biodiversity loss.

An Agenda for Reclamation and Rehabilitation

As a nation, we are at a crossroads. GAAS, therefore, wishes to impress on both the government and stakeholders the urgency of adopting the following measures while we rethink the best ways to exploit our natural resources:

1. A geospatial analysis, over a 10-year period, using Remote Sensing and Geographic Information Systems (RSGIS) to show the open sores of illegal

- mining in our landscapes and waterscapes and assess the damage to our habitats;
2. A national audit of the soils and water bodies polluted by agrochemicals and hazardous organo-metallic chemicals, such as mercury, from mining – there should be suggested solutions by experts to address the problem;
 3. A survey for and assessment of microplastic suspensions floating on our fresh and marine water bodies, which are consumed by aquatic organisms and eventually enter our food chain;
 4. A survey of health implications for communities in the surface mining areas and an assessment of the impact of mining on the health of the people so affected; and
 5. A survey of livelihood losses of communities affected by mining and an estimate of socio-economic implications such as the loss of employment, especially for the youth.

We believe that these surveys and analyses will put Ghana in a better position to assess the damage done and to come up with a comprehensive plan of action to reclaim our health, lands and forests. In making these demands, we remind the government that state and non-state institutions whose mandates are to protect and secure the peaceful functioning of the Ghanaian environmental space should be adequately resourced and should not be under any political influence or pressure whatsoever.

Conclusion

Illegal mining is destroying the country's lands, rivers and forests. Although mining has been practised over decades in Ghana, wanton environmental destruction has taken a new dimension with adverse consequences, such as the destruction of water bodies and farmlands and the use of hazardous chemicals with long-term damage to our health and vital organs. As we have seen, half-hearted attempts to stop illegal mining will not work. What is required is effective regulation and its enforcement, which must be backed by strong political will and commitment, a common understanding of the threats posed by illegal mining, and a stakeholder consensus on the way forward.

This is a clarion call to all Ghanaians to rally behind a good cause that holds government and community leaders accountable. Collective and sustained efforts are required to deal with the menace of illegal mining. We invite the media to commence and sustain a strong movement that names and shames persons who are found to be behind this menace while highlighting and rewarding those strongly at the forefront of fighting illegal mining. We also invite Parliament, the Judiciary and non-state actors such as the National House of Chiefs, the Trades Union Congress, civil society, professional associations, faith-based organisations and students – indeed, the entire Ghanaian populace – to join forces in combating illegal mining and its deleterious effects, which pose an existential threat to all of us and future generations. The Academy is committed and ready to collaborate with all stakeholders in the fight to stop illegal mining and its destructive effects on our people and our land.

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Silicosis, persistent pneumothorax, and respiratory failure: Grim consequences of galamsey

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Abstract

Illegal small-scale gold mining (galamsey) is often plagued with a deleterious working environment and a lack of proper safety protocols. In this case report, a 32-year-old male galamsey miner presented with progressive shortness of breath, cough, chest pain and weight loss. He was suspected of having silicosis and persistent pneumothorax. Surgery could not be done due to the poor state of the lungs. Despite immediate medical intervention, including chest tube insertion, the patient's condition deteriorated rapidly, and he succumbed to respiratory failure. This case report is highly representative of the medical condition of many galamsey workers. There is an urgent need for intensified safety measures, regulatory enforcement, and improved healthcare access. Concerted efforts of various stakeholder collaborations are key to creating a safer and more sustainable mining industry.

Keywords: Galamsey, silicosis, respiratory failure, gold mining

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INTRODUCTION

Illegal small-scale gold mining, commonly called galamsey in Ghana, is often characterised by dangerous working conditions and a lack of proper safety measures. Gold is a major export commodity that contributes significantly to gross domestic product (GDP) and employs hundreds of thousands of individuals in Ghana [1,2]. The devastation of illegal mining in Ghanaian communities has been reported to include water pollution, environmental degradation, impoverished local communities and a lack of basic amenities [3]. Gold miners who worked underground are known to have health problems, including decreased life expectancy, increased frequency of cancers, pulmonary tuberculosis (PTB), silicosis, asbestosis and other lung diseases [1,3–5]. Small-scale illegal miners in Ghana (galamsey workers) are usually unprotected and thus inhale mining dust containing

silica and other metals, which are then trapped in the lungs and pleura resulting in lung diseases. In this case report, we present a case of a galamsey worker who developed severe silicosis and pneumothorax and succumbed to respiratory failure.

Case

Our case involves a 32-year-old male who has been a galamsey gold miner for over a decade. After years of unprotected illegal mining, the patient developed shortness of breath, cough, chest pain and weight loss of two years duration. The symptoms, which were intermittent, later became severe and progressive three months prior, for which reason he visited various health facilities without improvement. He was referred to the Accident and Emergency Department of Tamale Teaching Hospital for further management. He had a past medical history of PTB that was treated two years ago. On examination, the patient was conscious, cachectic and in severe respiratory distress. His oxygen saturation was 75% on room air, respiratory rate

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was 26 cycles per minute, blood pressure was 139/92 mmHg, pulse was 134 beats per minute, and temperature was 36.6°C. There was no cyanosis, finger clubbing or palpable lymphadenopathy. Chest expansion was decreased bilaterally, percussion note was resonant for most lung zones and hyper resonant in the left upper lung zone, and air entry was reduced bilaterally with bronchial breath sounds in the left upper lung zone and crepitations in both lung zones. All other examination findings were unremarkable. Chest x-ray after initial stabilisation

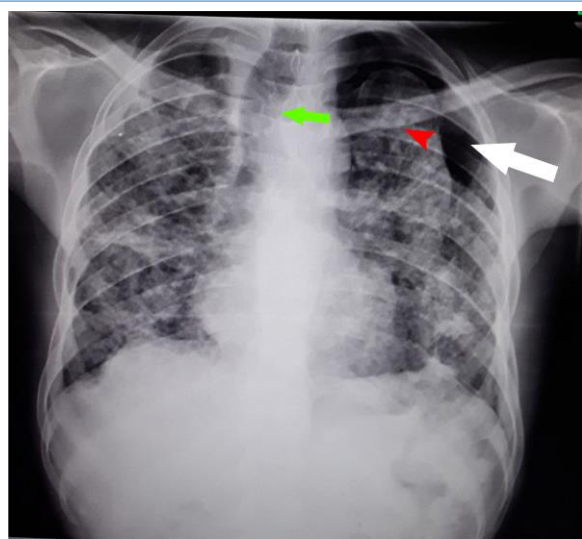


Figure 1. A chest x-ray of the patient showed a collapsed left lung with irregular opacities and a fine reticular pattern of the lung fields (red arrow), left pneumothorax (white arrow) and tracheal deviation to the right (green arrow).

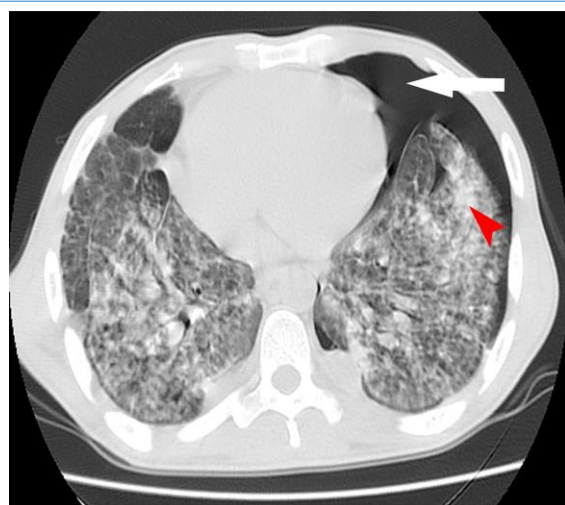


Figure 2. Chest CT scan image showing diffuse reticulonodular opacities within both lungs and a collapsed left lung (red arrow) in a background of ground-glass opacification with left pneumothorax (white arrow).

revealed irregular opacities with a fine reticular pattern of the lung fields and a left pneumothorax (Figure 1).

An initial diagnosis of left secondary spontaneous pneumothorax secondary to pneumoconiosis was made, and a chest tube was passed. Despite the chest tube insertion, the patient's condition did not improve and was complicated by pneumonia. A chest CT revealed diffuse reticulonodular opacities within both lungs in a background of ground-glass opacification, bilateral upper lobar consolidations and a left pneumothorax (Figure 2).

He was discharged home on oxygen with minimal pneumothorax after three weeks of admission when he was clinically stable but still dependent on minimal oxygen. The chest tube was removed after clamping it over 24 hours without significant change. The patient presented after two months to the thoracic surgery clinic with similar symptoms and a pneumothorax identical to the previous admission. He was admitted for oxygen treatment and chest tube insertion on account of persisting pneumothorax and respiratory distress. Despite immediate medical intervention, including chest tube insertion, the patient's condition deteriorated rapidly. Surgery was not considered due to the extensive lung fibrosis. His weakened respiratory system from previous PTB ravaged by silicosis was unable to sustain normal oxygenation. The patient ultimately succumbed to respiratory failure.

DISCUSSION

This case of a man who developed severe silicosis complicated by persistent pneumothorax resulting in respiratory failure and difficulty in accessing early intervention after working for decades as a galamsey gold miner presents a stark reality of the multifaceted health risk associated with such activities. Silicosis remains a significant public health issue, and the inhalation of tiny particles of silica causes inflammation and fibrosis in the lung tissue. The risk of silicosis is dose-dependent and increases exponentially with cumulative dust dose. The major source of silicosis-related diseases, including cancer, PTB and other respiratory diseases, is occupational exposure to silica from mining gold [6,7]. The most common cause of pneumoconiosis in gold miners is silicosis, with a reported prevalence of 11-37% [7]. With most mining companies in Ghana and galamsey activities still using an open-pit method of mining, which is reported to be most devastating to human health and the environment, mining remains the most hazardous occupation in the world irrespective of its short or long-term consequences [2,8].

The underlying conditions of previous PTB and silicosis exacerbated the pneumothorax or vice versa, making it more difficult for the lung to re-expand. The cause of the persistent pneumothorax was not obvious from the clinical findings and images. There was no trapped lung, as was evident on the CT scan. However, due to the extent of lung

destruction over the years, bronchopleural fistula is likely, although the typical imaging characteristics of bronchopleural fistula were not evident on the chest CT, and there was no spontaneous bubbling of the underwater seal. Progressive lung fibrosis from pneumoconiosis could also adversely affect lung healing and delay the resolution of pneumothorax. Previous researchers have made recommendations including but not limited to monitoring of dust levels, screening, medical examination, continuous education on safety measures of mining, streamlining activities of galamsey, coordination of related agencies in preventing exposure and social-economic support for affected communities to help prevent galamsey related diseases [1,6,9].

Conclusion

The case of this male patient with severe silicosis and pneumothorax resulting from illegal small-scale gold mining serves as a distressing reminder of the urgent need for enhanced safety measures, regulatory enforcement, and improved healthcare access in these high-risk occupations.

DECLARATIONS

Ethical consideration

Informed consent was obtained from the patient's caregivers for this report. All ethical issues have been considered to protect the patient's rights.

Consent to publish

All authors agreed on the content of the final paper.

Funding

None

Competing Interest

None

Author contributions

AI was involved in the study concept, design, and case management. MY was involved in the drafting of the report. All authors were involved in the interpretation of data, critical revision of the manuscript for important intellectual content and review of the final report.

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Availability of data

The data for this work is available upon request from the corresponding author.

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